The London School of Economics and Political Science

Who Runs the Radio Commons? The Role of Strategic Associations in Governing Transnational Common Pool Resources

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Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

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Abstract

This thesis investigates how collective action is achieved in the governance of transnational common pool resources, taking the example of the electromagnetic radio spectrum as a global common. The thesis asks what determines variation in operational and collective choice property arrangements in common pool resources such as the radio spectrum. The radio spectrum represents the totality of radio frequencies used for wireless communications around the world. It is a transnational resource that exhibits properties of other common pool resources: a) high rivalry in consumption and b) difficulty in excluding non-contributing beneficiaries from its use. This study demonstrates that the presence of a public actor – even one with established authority at transnational level such as the Commission of the European Union – cannot fully explain variations in the configuration of property arrangements in the radio resource. Instead, this study finds that private actors in the electronic communications industry – i.e. service operators and system developers – define rules of access and rules of use in the transnational radio resource, by means of negotiating the configuration of technology systems used to extract value from the resource. In addition, this study finds that industry actors are able to define common operational rules to access and use a transnational frequency pool even in complex situations of heterogeneous economic interests and heterogeneous technology capabilities. They reduce uncertainty in these complex situations by increasing participation in decision-making and by developing mechanisms of information exchange and mutual monitoring in industry associations. When industry actors agree these common rules of management, and reinforce them with common rules of exclusion, they are more likely to negotiate operational arrangements based on principles of common exclusive property rather than individual exclusive property in the transnational radio resource. These findings are derived from the analysis of four case studies, which trace the development of operational rules in five radio frequency bands across time. By revealing the central role of industry associations in defining property arrangements in transnational commons such as the radio spectrum, this research seeks to contribute to the debate about the nature and scope of private transnational governance of common goods.

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List of Acronyms

Acronym	Description
1G	First generation mobile communications
2.5G	Evolutionary second generation mobile communications, such as GPRS and EDGE
2G	Second generation mobile communications
3G	Third generation mobile communications
3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2
4G	Fourth generation mobile communications
ACTS	Research Programme in Advanced Telecommunications Technologies and Services of the European Union (1994-1998)
AKE	Electronic switch manufactured by Ericsson
AMPS	Advanced Mobile Phone System
ANSI	American National Standards Institute
ANSI T1P1	Technical Subcomittee of the American National Standards Institute
ARIB	Association of Radio Industries and Businesses in Japan
AT&T	American Telephone and Telegraph
ATDMA	Advanced Mobile Access Project of the European RACE Programme
AXE	Circuit switched digital telephone exchange manufactured by Ericsson
B-ISDN	Broadband Integrated Services Digital Network
CCIR	International Radio Consultative Committee of the International Telecommunication Union
CCITT	Former Comité Consultatif International Téléphonique et Télégraphique, currently ITU-T
CDMA	Code Division Multiple Access, an access method of the radio spectrum which assigns a code to each call spreading it over all available frequencies
CEC	Commission of European Communities
CEPT	European Conference of Postal and Telecommunications Administrations
CGCT	Compagnie Générale de Constructions Téléphoniques
CITEL	Inter-American Telecommunications Commission
CODIT	Code Division Testbed Project of the European RACE Programme

COST	The European Co-operation in Science and Technology Programme
CPR	Common pool resource
DBP	German Bundespost
DCS	Digital Cellular Service, GSM based services deployed in the 1800MHz band in the United Kingdom
DTT or DTTV	Digital Terrestrial Television
DECT	Digital Enhanced Cordless Telecommunications
DGT	Direction Générale des Télécommunications
DVB	Digital television standard
DVB-C	Cable digital television standard
DVB-S	Satellite digital television standard
DVB-T	Terrestrial digital television standard
EBU	European Broadcasting Union
EC	European Communities
ECU	European Currency Unit
EDGE	Enhanced Data Rates for GSM Evolution, a packet switched service associated with 2.5G and 3G mobile communication systems
EEC	European Economic Community
EFTA	European Free Trade Association
EPC	Evolved Packet Core
ERC	European Radiocommunications Committee
ESPRIT	European Strategic Program on Research in Information Technology
ETSI	European Telecommunications Standard Institute
ETSI BRAN	European Telecommunications Standard Institute, Broadband Networks
EU	European Union
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom

Europe Region	In the administration of the radio spectrum, the Europe Region focuses on 40 Member States within ITU Region 1, comprising Andorra, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Czech Rep., Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Vatican, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, The Former Yugoslav Republic of Macedonia, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, San Marino, Spain, Slovenia, Sweden, Switzerland, Turkey, United Kingdom, Serbia
E-UTRA	Universal Terrestrial Radio Access interface used for the UMTS third generation mobile communications standard
FCC	Federal Communications Commission, the regulatory agency for electronic communications in the United States
FDMA	Frequency Division Multiple Access, a method of radio spectrum use which assigns each call to a frequency, used in analogue mobile communications
FMK	Digital radio interface translated as mobile communication of the future, developed by Nordic operators in the early 1980s
FPLMTS	Future Public Land Mobile Telecommunication System, a third generation mobile system later renamed IMT-2000
FRAMES	Future Radio Wideband Multiple Access System Project of the European ACTS Programme
FRAND	Fair, reasonable and non-discriminatory terms for licensing intellectual property
GATS	General Agreement on Trade in Services
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GHz	A unit of frequency in radio communications, equivalent to 1,000 MHz
GMS-CEPT	Groupe Spécial Mobile, an expert group for the development of second generation digital telecommunication standards in Europe, part of European Conference of Postal and Telecommunications Administrations (CEPT)
GPRS	General Packet Radio Service, associated with 2.5G and 3G mobile communication systems
GSM	Global System for Mobile Communications (originally Groupe Spécial Mobile)
GSM MoU	Groupe Spécial Mobile Memorandum of Understanding
GSM+	Enhanced data services based on the GSM core network
GSMA	GSM Association
HDTV	High Definition Television

HIPERLAN	High Performance European Radio LAN
HPSA	High Speed Packet Access
HSCDS	Evolutionary Standard of GSM, associated with GSM+ or 2.5G mobile communication systems
IAD	Institutional Analysis and Development framework
iDEN	Integrated Digital Enhanced Network, a mobile telecommunications standard developed by Motorola
IEEE	Institute of Electrical and Electronics Engineers
IMT-2000	International Mobile Telecommunications 2000, a global family of standard for third generation mobile communications
IMT-Advanced	International Mobile Telecommunications Advanced, a global standard for fourth generation mobile communications
IP-Based Networks	Electronic communications networks based on internet protocol
IPR	Intellectual property rights
IRC	International Radiotelegraph Conference
ISDN	Integrated Services Digital Network
ITU	International Telecommunication Union
ITU-R	ITU Radicommunication Sector
ITU-T	The ITU Telecommunication Standardisation Sector
Kc/s	Kilo cycles per second, a measure of radio wave frequencies
LAN	Local Area Network
LTE	Long-Term Evolution, marketed as fourth generation mobile communication systems, now 3G Advanced or 3.5G
MAC	Media Access Control
MHz	Megahertz, a measure of radio wave frequencies
MIB	Mobile Industry Backing Terrestrial Spectrum for IMT
MoU	Memorandum of Understanding
NCR	National Cash Register
NGMN	Next Generation Mobile Network Alliance
NGO	Non-governmental organisation
NMT	Nordic Mobile Telephone Standard
OECD	Organisation for Economic Cooperation and Development
OFCOM	The Office of Communications in the UK
OFDM	Orthogonal Frequency Division Multiplexing
ONP	Open Network Provision Framework
PCS	Personalised Communications System

PDC	Personal Digital Cellular, a 2G mobile telecommunications standard developed and deployed in Japan
PHY	Physical layer
PSDN	Public Switched Telephone Network
PTT	Postal Telegraph and Telephone unit/ agency of government administering (and most times operating) telecommunications services
QoS	Quality of Service, a concept linked to the overall performance of a mobile network for specific applications
R&D	Research and Development
RACE	Research into Advanced Communications in Europe
RRC	Regional Radiocommunication Conference of ITU
RSPG	Radio Spectrum Policy Group of the European Commission
SAE	System Architecture Evolution
SIP	Societa Italiana per L'Esercizio Telefonico
SOG-T	Senior Officials Group on Telecommunications
STET	Italian Societa Finanziaria Telefonica
TACS	Total Access Communication System
TC SMG	Special Mobile Group Technical Committee of ETSI
TD-CDMA	Time Division - Code Division Multiple Access, a method of radio spectrum use based on spreading spectrum across multiple time slots
TDMA	Time Division Multiple Access, a method of radio spectrum use which assigns each call a portion of time on a frequency, hopping calls periodically
TEU	Treaty of the European Union
UHF	Ultra high frequency
UMTS	Universal Mobile Telecommunications System
UMTS Forum	Non-profit association promoting UMTS for third generation mobile communications
US TDMA	Digital Advanced Mobile Phone Service or D-AMPS, a digital cellular radio standard developed and deployed largely in the United States
WARC	World Administrative Radio Conference of the International Telecommunication Union
W-CDMA	Wide Band Code Division Multiple Band Access, a standard used for third generation mobile communications
WECA	Wireless Ethernet Compatibility Alliance

Western Europe	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom
Wi-Fi	An application of standard IEEE 802.11 for Wireless Local Area Networks
WiMAX	Worldwide Interoperability for Microwave Access, standardised as IEEE 802.16
WLAN	Wireless Local Area Network
WRC	World Radio Conference of the ITU
WTO	World Trade Organisation
WWI	Wireless World Initiative
WWRF	Wireless World Research Forum

Introduction

The study of collective action, with its application in different social situations, including situations of shared resources, has been a central area of inquiry in the social sciences. Over time, studies have primarily focused on the inherent difficulties of groups to achieve collective action and to provide public goods (Hardin 1968, Hume 1740, Olson 1965). In short, these problems of collective action describe a situation where individuals fail to sustainably achieve a group goal, even though each individual would benefit from contributing towards that goal. Philosopher David Hume was one of the first to describe this situation in *A Treaties of Human Nature* (1740), making direct reference to the inherent predisposition to collective inaction in shared resources:

> "Two neighbours may agree to drain a meadow, which they possess in common. […] But 'tis very difficult, and indeed impossible, that a thousand persons shou'd agree in any such action; it being difficult for them to concert so complicated a design, and still more difficult for them to execute it; while each seeks a pretext to free himself of the trouble and expence, and wou'd lay the whole burden on others" (1740: 538).

What Hume so accurately describes is not only a general predisposition to collective inaction, but also the predisposition to free-ride on collective arrangements produced by others in a natural setting that has the properties of a common pool resource – i.e. a shared resource characterised by high rivalry of consumption and difficulty of excluding non-contributing beneficiaries from its use (Dasgupta and Heal 1979, Friedman 1971, Gardner et al 1990, Gibson et al 2000, Ostrom 1990, Ostrom 2003). Recently, the study of collective action in shared resources has been revived following considerable research into the institutional arrangements that individuals create in order to cope with similar problems of organisation and provision (Feeny et al 1990, Ostrom et al 1988, Ostrom 1990, Wade 1987). E. Ostrom's contribution challenged established assumptions in political economy, which proposed that groups can achieve stable and sustainable collective arrangements in shared resources only through public or individual ownership. In short, Ostrom's research found that individuals, faced with problems of collective action in common resources, commit themselves to a variety of cooperative strategies that are "rarely either private or public" (Ostrom 1990: 14, Ostrom 1994, Ostrom et al 2012).

Building an evidence-based theory of collective action, E. Ostrom showed that clearly defined groups are able to develop, monitor and enforce common property regimes that ensure the sustainable access and use of a common pool resource. Ostrom's approach, however, did not reject the rational choice tradition of collective action and maintained that individuals in a group are "purposeful actors who respond to incentives", albeit in the presence of institutions that shape these incentives (Pennington 2012: 22). Since the development of this new institutional approach in the public choice literature[1], there has been a growing interest in the study of institutional arrangements that could lead to a more stable and sustainable management of shared resource (Agrawal 2003, Bromley et al 1992, Cox et al 2010). As a result, a growing number of studies have designed, discussed and proposed institutional arrangements based on the self-governance of global commons such as our shared waters, forests, fossil fuels, atmosphere and even outerspace (Cox et al 2010, Singh 1994, Weeden and Chow 2011). There is no doubt that these studies have made a considerable contribution to evaluating alternative designs of institutional arrangements, which could lead to stable and sustainable management of shared resources at the global level. However, as some scholars have pointed out, this approach has also led to the identification of too great a variety of conditions for sustainable management (Agrawal 2003), while diverting attention from the original analysis of the problems of coordination that take place in large scale commons organised in different ways at local, national, transnational and international level (Héritier 2002, Holzinger 2008). Therefore, this thesis attempts to refocus our analytical lenses on why and how resource users decide to organise and collectively supply institutions in order to manage large-scale common pool resources of a transnational nature.

[1] Aligica and Boettke (2011) and Aligica and Sabetti (2014) have dedicated considerable attention to the wider contribution of the Bloomington School in forwarding a new institutionalist approach to theories of public choice. According to Aligica and Boettke (2011), this approach puts forward a new perspective on human action and, as a result, a new perspective of social order that connect the theory of choice with the theory of institutions through learning and knowledge exchanges (2011: 29). Thus, Aligica and Boettke (2011) show that the "study of the commons emerges from a broader and deeper intellectual perspective" that rests of two evidence-based findings. First, the evidence of polycentric governance, which questions "the monocentric vision of social order and the market vs state dichotomy" (2011: 30). Second, the evidence of a social order based on knowledge and learning processes that coexist with other human processes based or derived from self-interestedness (2011: 30).

This thesis recognises the essential contribution made by the literature studying the governance of common pool resources to our understanding of property systems[2], rule systems[3] and governance regimes[4] in shared resources. There is, in fact, good reason to question whether public property and/or individual private property represent the only solutions to achieving sustainable governance of shared resources. There is also good reason to question whether heuristics based on the hierarchical governance of the state, the horizontal governance of the market or the spontaneous governance of the community produce discrete property solutions that can be described as public, private

[2] Property systems or property arrangements define the bundle of property rights that can be derived from a resource. Property systems do not refer to a single type of right, but to "an aggregate of rights" (Buck 1998: 3). This thesis will refer to property systems as an aggregate of two categories of rights – operational property rights and collective choice property rights – as derived from the rules regulating the consumption and maintenance of the global resource (Cole and Ostrom 2012, Schlager and Ostrom 1992). A discussion about these categories of rights is provided in *Section 1.1.4*. Briefly, operational property rights refer to the rights of access (right to enter) and the right of use (right of withdrawal or extraction) of a resource, whereas collective choice rights refer to rights of management (to regulate), rights of exclusion (to determining access) and rights of alienation (to transfer management or exclusion rights), as defined by Schlager and Ostrom (1992: 251).

[3] In this thesis, the term "rules" does not follow the definitions of rules as "rules of the game" in the rational analysis of collective action. Thus, rules are the artefacts subject to human intervention – rather than physical or behavioural laws – "by which we intervene to change the structure of incentives" (Ostrom 1986). Thus, rules order relationships between individuals by providing stability of expectations and by limiting uncertainty (Ostrom 1990: 53). Operational rights as well as collective choice rights in the commons correspond to operational rules and collective choice rules, which are also nested in one another (Ostrom 1990: 51).

[4] This thesis acknowledges the debate around the definition of "modes of governance" as referring to politics, polity or policy (Treib et al 2007). Because "modes of governance" has been exposed to concept stretching, this thesis adopts the position that the core meaning of governance refers to "steering and coordination of interdependent (usually collective) actors based on institutionalised rule systems" (Benz qtd in Treib et al 2007: 3). Thus, Treib et al (2007) suggest that one way of limiting the boundaries of the concept, while allowing it to capture the politics, polity and policy dimensions, would be to locate it on a continuum between public authority and societal self-organisation (2007: 5). This allows a mode of governance to include: a) the actor dimension (state versus non-state actors), b) the polity dimension (formalised versus non-formalised rules) and c) the policy dimension (procedural versus material rules). Lastly, special attention needs to be paid to the relationship between a system of governance and a mode of governance. V. Ostrom refers to a "system of governance" as polycentric depending on "the distribution of ruleship functions traditionally ascribed to a sovereign" (in Aligica and Sabetti 2014: 54). By this definition, polycentricity would be covered under the polity dimension of a mode of governance, rather than by allowing a distinction between a system of governance and a mode of governance.

or common (Streeck and Schmitter 1985). Recent research has revealed a wide range of shared resources, each prone to different types of collective dilemmas and each revealing different rules and different configurations of authority for developing, monitoring and enforcing these rules. From local natural resources such as fisheries, pastures or forests (Bromley et al 1992, Gibson et al 2000, Barkin and Shambaugh 1999) to global ones such as the oceans, the atmosphere or the electromagnetic radio spectrum (Benkler 1999, Dietz et al 2003, Hackett 2011, Levin 1971, Ostrom et al 1999), to man-made ones such as city commons, scientific commons and knowledge commons like the worldwideweb (Hess 1995, Hess and Ostrom 2003, Nelson 2003), all these resources exhibit a variety of institutional arrangements that govern them, some more successfully than others. A quick analysis of these shared resources reveals that they exhibit multiple property systems based on a variety of rules of access and use ("*operational rules*") as well a variety of rules of management, exclusion and alienation ("*collective choice rules*"), which concern socio-economic activity in the resource[5] (Cole and Ostrom 2012, Schlager and Ostrom 1992). Moreover, rule-making, monitoring and enforcement are rarely concentrated in a single and formalised node of authority. Instead, they are arranged in polycentric systems of governance comprising both public and private entities with different responsibilities in the wider system of authority that defines, monitors and enforces these rules (V. Ostrom 1999, Ostrom et al 2012). It is, thus, this diversity that points at the difficulty of boxing property arrangements of transnational resources into private, common or public. And it is this diversity that makes it important and, indeed, fascinating to refocus our attention on the strategies employed by direct resource users to negotiate the supply of such diverse institutions in the context of "today's bargained economies and societies" (Streeck and Schmitter 1985: 3).

The electromagnetic radio spectrum is a very good example to enquire into the complex logic of collective action in transnational commons. The radio spectrum – representing the totality of radio frequencies used for wireless communications around the world[6] –

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[5] See supra note 2 for a definition of these rights. Also *see Section 1.1.4* for a more detailed discussion of these rights, based on the work by Schlager and Ostrom (1992) and Cole and Ostrom (2012).

[6] The radio spectrum refers to a part of the electromagnetic spectrum ranging from approximately 3KHz to 300GHz. Radio frequencies in this part of the electromagnetic spectrum are largely but not entirely designated for wireless communications used in different sectors such as defence, aviation, broadcasting, mobile telecommunications.

is a transnational natural resource predisposed to recognised dilemmas in the commons. Radio frequencies are natural resources shared by a group of users characterised by increased rivalry of consumption, whereby extraction by one user affects extraction by another user, as well as by increased difficulty of excluding users (Coase 1959, Vany et al 1969, Faulhaber 2005). However, rather than being exposed to permanent congestion or exhaustion of supply, the radio spectrum has been governed by relatively stable and diverse institutions since its first use for mobile communications in the late 19th century (Benkler 1999, Benkler 2012, Faulhaber 2006, Lehr and Crowcroft 2005). The answer to this stable governance, at least by comparison with other global commons (Buck 1998, Vogler 2000), has been largely attributed to the authority of public actors – be they governments or regulatory agencies – to allocate, redistribute or open access onto the radio resource under different conditions but by centralised means.

Thus, considerable attention has been paid to the methods used by governments or regulatory agencies to manage radio frequencies by administering exclusive use (Shelanski and Huber 1998), by creating secondary markets for flexible exclusive use (Cave et al 2007, Vany et al 1969) or by opening up frequencies for common use (Brito 2006, Benkler 2012). However, this perspective is challenged in this thesis on two grounds. First, it does not fully account for dynamics at the transnational level, given that the radio spectrum is an inherently transnational resource and given that the common good[7] derived from it – i.e. wireless communications – is inherently mobile. Second, it does not fully account for the diversity of property arrangements that make up the governance of radio frequencies beyond those prescribed by the formal authority of national public actors.

This thesis will only look at the organisation of radio frequencies designated for commercial use in wireless electronic communications (voice and data for communication services) and will not consider the organisation of radio frequencies used for non-commercial use such as public safety, emergency services or defence.

[7] This thesis adopts the definition of "common goods" put forward by Holzinger (2008). "Common goods will be used as a synonym for all goods that are not purely private. […] Common goods are defined by the presence of externalities". As Holzinger (2008) noted, "this definition has the advantage of capturing a number of different notions of goods such as pure public goods, club goods, CPRs, congestibles or network goods" (Holzinger 2008: 28).

In order to explain the diversity of property systems encountered in the governance of radio frequencies, this thesis asks the following research question:

What determines the specific configuration of rights of access and use (operational property rights) and rights of management and exclusion (collective choice property rights) in a transnational common pool resource such as the radio spectrum?

The thesis starts from the assumptions put forward by E. Ostrom that "a set of principals, faced with a collective action problem, can solve 1) the problem of supplying a new set of institutions, 2) the problem of making credible commitments and 3) the problem of mutual monitoring" (Ostrom 1990: 42). In the case of the radio spectrum for commercial wireless communications, these principals are the private actors that draw direct economic benefit from this transnational resource: a) service operators of wireless communications and b) product/infrastructure developers of wireless communications. These private actors are businesses with national, transnational and international presence and are the direct extractors and creators of economic value in the (commercial) radio resource. They extract economic value from the spectrum resource by using wireless technology and, at the same time, they create economic value by using the resource as input into the production of wireless communications as common goods. During this complex extraction and production process, they sometimes choose to coordinate in industry associations formed around the development of technology solutions for the use of wireless frequencies. And, as E. Ostrom noted with reference to similar resources, these industrial actors use technology, which they or others produce, in order to "establish and sustain property rights on the resource" (E. Ostrom in Buck 1998: xiii).

In this context, the thesis tests theoretical assumptions about the type of property systems most likely to result from a particular configuration of private interests, as derived from the public choice theory of collective action[8]. First, the thesis tests whether the organisation of private interests is the result of (re-)distributive measures

[8] As indicated above, E. Ostrom's work is situated within the rational-choice tradition in economic and political theory (Pennington 2012: 22), with a particular mention that Ostrom's work recognizes that actor strategies are constrained by bounded rationality and correspond to various choice dimensions – operational, collective choice, constitutional – that, in an institutional setting, are formed as choices of ideas and knowledge, which ultimately create given rule configurations or social orders (Aligica and Boettke 2009: 131).

taken by a public actor with rule-making authority in the radio spectrum at transnational level. Second, the thesis tests whether an association of industry actors, benefiting from reduced levels of diversity of interests among its members, is more likely to supply a property system based on low rivalry among members and high excludability of non-members – i.e. exclusive common property. Conversely, the thesis tests whether an association of industry actors, characterised by high levels of diversity of interests and unequal distribution of capabilities among members, is more likely to supply a property system based on high rivalry among members and high excludability of non-members – i.e. exclusive individual property. Third, the thesis asks whether the organisation of radio frequencies on principles of exclusive common property is less likely to require the intervention of a public actor in monitoring commitments to operational rules on the spectrum resource. Conversely, the thesis asks whether the organisation of radio frequencies on principles of exclusive individual property is more likely to require the intervention of a public actor in monitoring operational rules on the spectrum resource.

This research brings three main findings to the study of property arrangements in transnational common pool resources such as the radio spectrum – i.e. transnational common pool resources that rely on technology systems in order "to extract value as well as to establish and sustain property systems on [them]" (Ostrom in Buck 1998: xiii). The first finding is that the radio spectrum is governed by varying configurations of authority for defining, monitoring and enforcing property systems across time. Specifically, this research finds that industry actors are very active at the stage of defining rules of access and rules of use in the transnational radio resource, by means of negotiating the configuration of technology systems used to extract value from the resource. The second finding is that, depending on their distribution of economic interests and technology capabilities, industry actors can stabilise newly defined operational rules with mechanisms of mutual monitoring. Specifically, and surprisingly, this research finds that complex situations of heterogeneous economic interests and heterogeneous technology capabilities do not result in collective inaction. On the contrary, these situations of heterogeneity result in sustained collective action achieved in formal and informal industry associations with greater participation of industry actors in the definition of operational rules as well as with more developed mechanisms of information exchange and mutual monitoring. The third finding is that, when industry actors agree common rules of management and common rules of exclusion, they lower the level of internal rivalry among them and, subsequently, they are more likely to negotiate property arrangements based on principles of common exclusive property than on principles of individual exclusive property. In situations when common rules of management and common rules of exclusion are agreed, industry actors are less likely to rely on the authority of the public actor to monitor their commitments to operational rules in the common pool. Overall, these findings are consistent with theories of private group action as discussed by Dunleavy (1991) or, more specifically, theories of associative action as put forward by Streeck and Schmitter (1985), who argue for a fourth model of social order – i.e. the "associative order" – in order to explain the presence of "collective self-interest" of industry groups manifested as a form of "private government" (Streeck and Schmitter 1985: 3, 10). Translated at the transnational level, these findings are consistent with theories of transnational private regulation as discussed by Scott, Cafaggi and Senden (2011), who illustrate diverse configurations of authority in defining, monitoring and enforcing transnational common goods between public and private actors.

The findings arrived at in this thesis are based on an in-depth analysis of four cases in the transnational organisation of the radio resource for the provision of commercial wireless communications. The cases address the regulation of five frequency bands in Europe, Region 1[9] of the radio spectrum, over different periods of time:

- The regulation of the 900 MHz band for second generation cellular digital mobile communications in the late 1980s
- The regulation of the 1.9 GHz and 2.1 GHz bands for third generation cellular digital mobile communications in the 1990s
- The regulation of the 800 MHz band for mobile broadband in the late 2000s
- The regulation of the 2.4 GHz and 5 GHz bands for wireless local area networks in the early 2000s

[9] For regulatory purposes, the International Telecommunications Union (ITU) has divided the world into three Radio Regions: *Region 1* comprising Europe, Middle East, Africa, the former Soviet Union; *Region 2* comprising North and South America and the Pacific; *Region 3* comprising South-East Asia, Australia and the Pacific Rim (ITU 2011). As it will be explained in *Chapter 1*, the Radio Regions are further divided into administrative sub-regions. Europe – which will be roughly defined as covering the geographical area of the European Conference of Postal and Telecommunications Administrations (CEPT) – is such a sub-region. See *List of Acronyms* for definitions and country list, noting that membership in the CEPT changed across time.

The case studies were selected based on the diversity of industry actors who draw a direct economic benefit from using the specified frequency band. First, the case studies are derived from sectors with diverse industry structures such as the mobile communications, broadcasting and information technology industry, which allows for variability in interests and capabilities among actors. Second, the case studies span across different stages in the liberalisation of the electronic communications sector, which allows for variability in the position of the public actor in the regulation of communications markets and for analysis of the position of the public actor vis-à-vis private actors in the regulation of the radio resource. Third, each case study follows over a decade of interactions among industry actors organised in associations at regional and global level. Each case study holds constant the geographic dimension of the radio spectrum, by focusing exclusively on the regulation of radio frequencies in Europe, Radio Region 1. This region has not been selected because of the presence of the European Union (EU) polity in the wider Europe, Radio Region 1, which could constitute a selection bias due to the existence of established venues of coordination within the EU. On the contrary, this region has been selected for recognised problems of collective action in sharing the radio resource at transnational level, due to the high number of industry actors, positioned in a significant number of jurisdictions, situated in a relatively limited geography compared with other radio spectrum regions (Tomlinson 1945, Savage 1989). The relatively high number of industrial actors interested in using a limited common resource provides variation in their preferences and in their capabilities, which helps test whether variations in private interests and in resources determine variations in the property arrangements witnessed in the radio spectrum. However, each case study accounts for the presence of the EU polity in the wider Europe, Radio Region 1. In fact, each case study reflects different stages in the development of the EU polity in the electronic communications sector, which helps test whether industry actors organise in response to the (re)-distributive preference of the European Commission as a transnational public actor and whether industry actors prefer its established policy venues to influence the choice of property arrangements in the regional radio resource.

The case studies are analysed using a combined method of process tracing and network analysis. Each case study follows a three-stage analysis into: a) the formation of actor strategies in the institutional setting for governing wireless communications; b) the negotiation of operational and collective choice rules based upon these actor strategies and c) the impact of the organisation of these actors on the choice of property systems that make up the regulation of each frequency band considered in the case studies. The method of process tracing is used in order to provide an internal account of these negotiations and is based on the analysis of meeting minutes of the *European Conference of Postal and Telecommunications Administrations* (CEPT), *the European Telecommunications Standards Institute* (ETSI), the *Institute of Electrical and Electronics Engineers* (IEEE) and the *International Telecommunications Union* (ITU). Each case study also contains the official positions of industry and policy experts present in key moments of the rule-making process. Network analysis, based on graph theory, is used to analyse the patterns of cooperation among industry actors involved in strategic associations, as recorded in the *SDC Platinum Database* by Thomson Reuters. This combined method of inquiry into the four case studies provides a thorough investigation into the diverse interests and resources of industry actors, the dynamics of their negotiations regarding the rule system that defines levels of rivalry and excludability among them as well as their position vis-à-vis public actors in the governance of the transnational radio resource.

This research makes several contributions to the study of collective action in contemporary transnational commons. First, it makes a contribution to our understanding of collective action in shared resources of a transnational nature (Buck 1998, Ostrom et al 1999, Vogler 2000, Wijkman 1982). Compared with other global commons – such as the high seas, the atmosphere or the outerspace – the radio spectrum is a shared resource that has been successfully appropriated by means of technological innovation without polluting, overexploiting or overcrowding it on a systematic basis. This thesis pays particular attention to the diversity of interests and the distribution of resources among private actors who are actively involved in producing new technologies that not only extract economic value from this natural resource but also permanently alter the degree of rivalry and the degree of excludability in the resource itself. Thus, this research makes a new contribution to the study of the governance of global commons that does not consider private actors as receivers but as conceivers of property systems that governs transnational commons.

Second, this research makes a contribution to our understanding of the role of associative action as "an additional source of social order" (Streeck and Schmitter 1985:

2). Streeck and Schmitter (1985) are some of the first to propose this type of order as defining contemporary modes of governance. Since then, organisational models resembling the private interest associations described by Schmitter and Streeck (1999) have also been identified in the transnational regulation of common goods (Hallström 2004, Cafaggi 2012, Scott et al 2011). This thesis makes a clear contribution to the growing specialist literature in private transnational regulation, by identifying the central role of private interest associations as rule-makers of transnational regimes for managing common goods and by postulating on situations when private interest associations share authority in monitoring or enforcing privately set rules and rights with public actors (Abbott and Snidal 2011, Buthe and Mattli 2011, Scott 2012, Werle 2001).

Third, this research makes a contribution to our understanding of property systems, particularly to the relationship between property systems, rule systems and modes of governance in common resources of a transnational nature. The diversity of property and regulatory arrangements identified in recent years (Cole and Ostrom 2012, German and Keeler 2010, Schlager and Ostrom 1992) has, indeed, come to question "naïve theories of property" (Eggertsson 1990) that assume the dominance of individual private property over hybrid forms of property (Dagan and Heller 2001, McKean 2000). This thesis pays particular attention to the property systems that results from collective arrangements negotiated by private actors organised in diverse industry associations. Thus, this research contributes to the literature that sees property systems as both explicit and hybrid, depending on the degree of rivalry and the degree of excludability negotiated by industry actors as direct users of transnational resources (Cole 2002, German and Keeler 2010, Ostrom 2002).

More broadly, this research offers insight into the regulation of network industries with a particular focus on the evolution of regulation of telecommunications and, more generally, electronic communications (Alexiadis and Cave 2010, Cave et al 2007, Lodge 2010b, Lodge and Stirton 2007). In particular, this thesis draws attention to cycles of technology innovation in wireless communications, which do not always follow policies for the wider electronic communications market but, instead, follow the dynamics of rivalry and exclusion that are being negotiated in the radio resource. Lastly, this thesis offers insight into the wider organisation of interests in the area of electronic communications outside the polity of the European Union. In particular, it draws attention to situations where industry actors, organised in private associations, prefer to negotiate and set rule systems outside the formal policy venues of the European Union (Kohler-Koch and Eising 1999, Eising 2004, Pollack 1994).

This thesis is presented as follows. **Chapter 1** introduces the wider theoretical framework, which sets this thesis along three general lines of inquiry: who has authority to solve problems of collective action in transnational shared resources; what configuration of interests and capabilities can solve problems of collective action in transnational shared resources; and by what institutional means. After the main theoretical discussion is introduced, the chapter applies these main lines of inquiry onto the early history of the radio spectrum to verify whether this resource offers appropriate grounds for analysis. **Chapter 2** introduces the main analytical framework to be applied across the cases, as well as the methods used for this analysis. It adopts a variant of the Institutional Analysis and Development (IAD) framework, as put forward by the literature on public choice institutionalism. **Chapters 3-6** provide the empirical evidence for this study, looking at the regulation of the frequency bands identified above. **Chapter 7** summarises the main findings of this study and discusses some of their implications to the wider literature on transnational private regulation and, specifically, on the governance of transnational common pool resources.

Chapter 1. Collective Action in Shared Resources: The Theoretical Framework

This chapter introduces the broad theoretical framework of the thesis, which looks at what determines the creation of new institutional arrangements designed to solve problems of collective action in shared resources. The chapter starts by outlining the common assumptions put forward by the rational choice theory of collective action, which portrays individuals as short-term self-interest maximizers, whose non-cooperative decisions trigger the tragic overuse of shared resources. The chapter aligns itself with the proposition that, while self-interest maximisation is a trait of human behaviour, it is by no means the only trait of human behaviour. Thus, this thesis aligns itself with the behavioural theory of collective action, which portrays individuals as holding complex motivational structures in conditions of bounded rationality (Ostrom 1998, Ostrom 2010, Simon 1957, Simon 1985). In the first part, the chapter frames the theoretical debate in relation with assumptions in rational choice theory about who solves problems of collective action, by what institutional means and at what level of provision. The chapter discusses the complexity of collective action problems in transnational resources in relation with these assumptions. In the second part, the chapter frames the theoretical debate in relation with institutional arrangements in the radio spectrum. The chapter shows that since the first use of radio frequencies for the production of wireless communications, private actors have been actively involved in the supply of property arrangements for the governance of the radio resource at transnational level. The chapter concludes that the radio spectrum represents fertile ground to test the relationship between public and private actors involved in decision-making processes about common resources, the strategies adopted by industry actors and the property arrangements that make up the governance of transnational common pool resources.

1.1 Framing the problem of collective action

The study of collective action is at the core of the social sciences. Collective action refers to “activities that require the coordination of efforts by two or more individuals” (Cornes and Sandler 1996: 324). Interdependence among participants is central to achieving a collective outcome. However, at times, participants find it difficult to exclude non-participants or non-contributing participants from drawing benefits from their collective action. This situation has been theorised as the problem of collective action (Olson 1965, Oliver et al 1985, Ostrom 2000). We witness problems of collective action at all levels of human interaction, from cleaning rotas in shared accommodations to citizen oversight of governments or to environmental protection in international relations. In fact, it is the pervasiveness of problems of collective action in our daily life that contributed to the development of a theory of collective action, which assumes individuals are unable to overcome the temptation to maximise their short-term, self-interest for the benefit of the collective good. Hence, the need for an external authority – the state or the firm – to intervene by applying inducements or sanctions in order to correct non-cooperative behaviour (Hardin 1998). Problems of collective action have found a variety of applications in the provision of common goods. Depending on their application, they have been referred to as "the free-rider problem" (Grossman and Hart 1980), "the credible commitment dilemma" (Lichbach 1995), "the tragedy of the commons" (Hardin 1968) or "the tragedy of open access" (Fox 1993)[10]. From an analytical perspective, they follow rational choice theory, which portrays humans as short-term, self-interested maximizers. From a methodological perspective, they apply a variety of techniques from thought experiments (Hardin 1968, Olson 1965) to game experiments (Coleman 1986) to iterated game experiments with institutional analysis (Axelrod 1981).

However, empirical evidence reveals that complete rationality is not as pervasive as the theory of rational choice has described it. High levels of cooperation – in the absence of an external authority capable of applying positive or negative incentives (Olson 1965) – can be found in diverse settings, from child rearing to mutual defence[11] (Ostrom 1998). Besides, considerable empirical evidence has revealed that small and medium-size resources have been sustainably shared without external intervention (Agrawal 2003, Agrawal and Ostrom 2001, Bromley et al 1992, Feeny et al 1990, Ostrom 1990). Based on this empirical evidence, even diverse groups can overcome difficulties in the provision of collective goods as long as they develop shared physical and social capital

[10] For a detailed, referenced outline of the different approaches see Ostrom (1998).

[11] In 1997, E. Ostrom opened the Presidential Address of the American Political Science Association with the argument: "You would not be reading this article if it were not for some of our ancestors learning how to undertake collective action to solve social dilemmas" (Ostrom 1998).

to regulate flows of income from a common resource (Keohane and Ostrom 1995, Ostrom 2000). The presence of cooperation, just as the presence of non-cooperation, indicates that the assumption of self-interest – as a defining characteristic of rational individuals – is more limited than rational choice theory would have it (Oliver et al 1985, Oliver 1993, Marwell et al 1988, Udehn 1993). Nevertheless, rejecting the assumption of non-cooperation altogether would be just as unrealistic as rejecting the assumption of cooperation in the first place. It is against this background that E. Ostrom advocated for a behavioural theory of collective action based on a model of individual behaviour consistent with empirical evidence of both cooperation and non-cooperation (Ostrom 1998: 1). In doing so, E. Ostrom showed that models of complete rationality have been incorrectly confused with a general theory of human behaviour (Ostrom 1998: 9). Instead, a general theory of human behaviour needs to include both models of complete rationality and models of bounded rationality[12] (Simon 1957, 1985).

In order to explain cooperation, behavioural models question some of the assumptions used by rational choice models of collective action. First, behavioural models refute that individuals have homogenous preferences. Thus, they recognise that individuals have different strategies in a particular situation of interdependence. Second, behavioural models refute that participants have perfect knowledge about the structure of the situation and about the probable strategies of others. Thus, they recognise that individuals do not have full information about a situation of interdependence. Third, behavioural models refute that individual decisions are made independently and/or simultaneously. Thus, they recognise that individuals communicate in situations of interdependence in order to solve collective problems (Oliver 1993: 274, Ostrom 1998: 4, Udehn 1993: 244).

Consequently, once we relax some of the assumptions of rationality without refuting them altogether, we can enquire into why and how individuals sometimes choose to

[12] Simon describes the parameters of his theory of bounded rationality as follows: "It is impossible for the behaviour of a single, isolated individual to reach any high degree of rationality. The number of alternatives he must explore is so great, the information he would need to evaluate them so vast that even an approximation of objective rationality is hard to conceive. Individual choice takes place in an environment of 'givens' – premises that are accepted by the subject a bases for his choice […]" (Simon 1957: 79). Thus, not only are decisions bounded by the incomplete nature of human knowledge at any point in time, but also by the organisational environment that frames all possible choices available to an individual.

cooperate and sometime don't (Ostrom 1998, Udehn 1993). This question constitutes the starting point of the present research. The next sections introduce how the problem of collective action has been theorised into a dilemma of open access in shared resources, particularly in common pool resources. The sections review the main debate between behavioural and rational choice assumptions about who solves dilemmas of open access, at what level of provision and by what institutional means, making particular reference to the complexity of these problems in transnational common pool resources.

1.1.1 The problem of collective action in shared resources

One of the first models describing the problem of collective action in shared resources has been "the tragedy of the commons" put forward by G. Hardin[13] (1968). The essence of this model is that, faced with the possibility of extracting benefits from a limited resource, every self-interested individual – i.e. rational individual – will try to maximise their gain rather than the collective gain of all beneficiaries, resulting in the overuse of the resource. Thus, the rational behaviour of individuals in this interdependent situation increases temptation to shirk from contributing towards the provision of a collective arrangement for managing the resource. The problem is exacerbated in situations where the shared resource has the characteristics of a common pool resource.

Ostrom defined a common pool resource as "a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use"[14] (Ostrom 1990: 30). Common pool resources are thus a type of common good broadly understood as a good that, unlike purely private goods, exhibits externalities (Holzinger 2008: 28, McKean 2000). Simply put, in common pool resources: a) exploitation by one user reduces the resource availability for other users and b) exclusion of beneficiaries through physical and institutional means is costly to achieve (Ostrom et al 1999: 278). Thus, common pool resources are characterised by high rivalry of consumption (similar to private goods) as

[13] It should be noted that a number of notable philosophers and economists, such as Hume (1940), Gordon (1954) and Scott (1955) had previously described such problems of collective action in shared resources.
[14] As Ostrom et al (1999: 278) noted, it is important to understand that "the term common-pool resources (CPRs) refers to resource systems regardless of the property rights involved".

well as high difficulty of excluding non-contributing users (similar to public goods). Therefore, it is the subtractibility of the resource, combined with the jointness of the resource system, which make common pool resources prone to congestion and/or overuse (Gardner et al 1990, Friedman 1971, Ostrom 1990: 32).

However, congestion and overuse – as consequences of problems of collective action – are not as endemic as rational choice theory would indicate. Over the past three decades, a substantial body of empirical evidence has revealed that individuals in interdependent situations, such as the use of a common pool resource, do not inevitably fail to provide collective arrangements for drawing economic benefits from the resource in a sustainable manner (Agrawal 2001, Baland and Platteau 1996, Bromley et al 1992, Cox et al 2010, Ostrom 1990). This evidence would then indicate that G. Hardin's conclusion - by which "freedom in the commons brings ruin to all" (1968: 1244) – had been misrepresented as a general law of human behaviour (Feeny et al 1990: 2). Moreover, G. Hardin argued that the only way to avoid the destruction of common resources is by the intervention of an external authority holding responsibility to regulate the behaviour of users through a set of positive and/or negative incentives that might resemble public or private enterprise (Hardin 1998). The next section tackles whether the presence of an external authority with ability to set different property arrangements represents the only way to solve problems of collective action in transnational common pool resources.

1.1.2 Who fixes problems of collective action in shared resources

In a later extension to the "tragedy of the commons", G. Hardin noted:

> "A 'managed commons' describes either socialism or the privatism of free enterprise. Either one may work, either one may fail: 'the devil is in the detail'. But with an unmanaged commons, you can forget about the devil: as overuse of resources reduces carrying capacity, ruin is inevitable" (G. Hardin 1998: 683).

Implicitly, Hardin's statement argues for the presence of an external authority to devise, monitor and enforce inclusive (socialism) or exclusive (privatism) property arrangements in the commons in order to manage them out of inevitable ruin. Hardin qualifies his statements, arguing that either arrangement can fail to produce sustainable governance of a common resource. Accordingly, the devil is in the detail. Then, intuitively, one needs to ask what detail this external intervention is trying to correct. Based upon rational assumptions, at a first level there is the problem of organisation and, at a second level, there is the problem of monitoring and enforcement.

In this situation, an external authority such as a government would solve the first problem by proposing a set of positive or negative incentives that corrects the 'ruinous' behaviour of individuals extracting value from a common pool. The totality of these regulatory measures represents a new institutional arrangement that would alter the rate of access (excludability) and the rate of use (subtractability) in a common pool in favour of public or private enterprise. The 'devil' would then rest in the second level problem of monitoring and enforcement. Empirical studies have shown that users of common pool resources can sometimes reject the privatisation or the nationalisation of shared resources, with adverse effects such as increasing costs of monitoring and enforcement (Feeny et al 1990, Ostrom et al 1999, Wade 1987). This situation reveals that an external authority does not always create, monitor and enforce sustainable institutional arrangements that avoid the 'ruin' of common resources.

Most importantly, a growing body of empirical evidence has revealed that direct resource users can create, monitor and enforce new institutional arrangements for successfully sharing resources, without the presence of an external authority (Bromley et al 1992, Blomquist and Ostrom 1985, Feeny et al 1990, Velez et al 2009). E. Ostrom referred to these direct users as appropriators because they withdraw units from the shared system and, generally, use these units as inputs for other production processes (1990: 31). Direct resource appropriators are, thus, capable and willing to restrict problems in the subtraction and provision of a common resource in order to obtain a higher joint benefit and/or to reduce joint harm (Ostrom 1990: 39). Examples of cooperation in the absence of external intervention have shown that appropriators can alter both first level (problems of organisation) and second level problems (problems of monitoring and enforcement) in common pool resources.

In fact, growing evidence of self-governance in common resources has led to the identification of a number of institutional choices that are more likely to result in stable and sustainable systems of governance (*Table 1.1*). Accordingly, the likelihood of stable and sustainable self-management of common pool resources rests upon the creation of rules of use (allocation) and rules of exclusion (boundary) that are specifically designed to respond to the properties of the resource and the attributes of the resource user group in conditions of accountable monitoring and sanctioning, following clearly defined authority in rule making, monitoring and enforcement (*Table 1.1*).

Table 1.1 Rule Systems as Institutional Choices for Sustainable Governance of Common Pool Resources

Rule System	**Description of type of rules affecting the likelihood of stable and sustainable governance of common pool resources**
Boundary rules	Specify clear exclusion mechanisms as a way of limiting access and avoid free-riding
Allocation rules	Specify clear use mechanism as a way of limiting uncertainty about potential disproportionate use, congestion or exhaustion of usable supply
Locally-adapted rules	Specify clear adaptability of rules to physical conditions of resource and attributes of group
Monitoring rules	Specify clear rules designed by group members or delegated members, with the ability to hold monitors accountable to the group
Enforcement rules	Specify clear sanctions on rule breakers, applied directly by group members or accountable delegates
Dispute resolution rules	Specify clear procedures to rapid conflict resolution mechanism among group members or group members and external authorities
Nested rule systems	Specify clear constitutional relationship between different layers of rule-making

Source: Based on Ostrom (1990), Pennington (2012).

Empirical evidence has revealed that appropriators change rules regarding the quantity, timing, location and/or technology of appropriation as well as rules about the overall maintenance of the resource in the short, medium and long term. And, similar to commons managed by external authority, their level of success remains "in the detail" (Hardin 1998). In fact, scholars promoting a closer analysis of the behaviour of resource users in conditions of conflict and cooperation have repeatedly stressed the importance of understanding why and how individuals interpret problems of appropriation and provision differently, rather than the importance of prescribing a set of optimal solutions to theoretically derived problems of collective action in the commons (Ostrom 1990: 56, Ostrom 1998: 5). Only then, a set of optimal principles for institutional design can be proposed, keeping in mind that resource users have different attributes just as resource systems have different properties that require different solutions (Buck 1998, Bromley et al 1992, Ostrom 2003, 2012).

Thus, this growing body of literature has uncovered that direct users can adopt a combination of self-interest, reciprocity, assurance, altruism and/or conformity when faced with a situation of interdependence for sustaining common pool resources (Ostrom 1998, Velez et al 2009). The behaviour direct users adopt in a situation of interdependence is then linked to how they learn about the benefits and costs of their actions as framed by the existing rules setting (Ostrom 1990: 33). The sustainability of the property arrangements they create is then dependent on their ability to tailor property rules to the attributes of the resource and the resource users group. Following from these findings, the next section discusses whether this diversity of sustainable arrangements is primarily witnessed in small and medium size natural commons, with a degree of remoteness from public or private enterprise, or whether it can also be witnessed in transnational commons.

1.1.3 Where to fix problems of collective action in shared resources

The study of self-organisation, self-monitoring and self-enforcement of institutional arrangements in shared resources has been largely conducted on small and medium-size common pool resources. The benefit of this approach is a closer examination of behavioural responses to structural problems as well as to the actions of other participants in the commons. The limitation of this approach, however, is the "scaling up" problem (Ostrom 2009, Ostrom et al 1999: 281). This problem translates in at least three ways. First, large-scale common pool resources, such as the atmosphere, the oceans or the worldwideweb, are transnational pools with considerably higher number and more diverse appropriators. Second, large-scale resources are predisposed to multiple conflicts derived from overlapping commons within them. For instance, the worldwideweb has been identified as hosting four distinct commons: a social commons, an information commons, a budget commons and a technical infrastructure commons (Hess 1995). Third, large-scale common pool resources might not be as remote from public or private enterprise as local grazing grounds, water basins or local fisheries but are exposed to the lack of hierarchical authority characteristic of international relations (Keohane and Ostrom 1995: 11-13).

These problems can complicate the frameworks used to evaluate institutional arrangements in transnational commons. First, users of global commons[15] are more diverse, have more complex motivational structures and interact in multi-level systems of governance at the local, national, regional and international level (Holzinger 2008, Keohane and Ostrom 1995). Consequently, regime analyses of global commons have revealed the limits of self-organisation, self-monitoring and self-enforcement in relation with the complexity of these transnational resources (Buck 1998, Goldman 1998, Vogler 2000, Wijkman 1982). Their results confirm that the technology for extracting value from these resources had evolved in the absence of an equal evolution of legal institutions designed to reduce negative externalities and avoid depletion (Ostrom in Buck 1998: xiii-xv). However, from an analytical perspective, these studies have focused primarily on the strategies of state actors at the international level. Regime analysis benefits from an understanding that governments cannot aggregate all interests within their jurisdictions and transpose them as clear positions in international negotiations. Besides, regime analysis recognises that non-state actors have some contribution in defining rules by providing policy expertise and coordination (Jackobsen 2000, Vogler 2000, Sell 2000). Yet, this analytical approach can sometimes restrict non-state actors to privileged beneficiaries of access to policy-making in exchange for the provision of otherwise costly knowledge and technical expertise (Buck 1998, Vogler 2000).

In transnational commons, this analytical approach can limit how we frame the problem and, most importantly, where we frame the solution to achieve a sustainable institutional arrangement. First of all, global commons have multiple uses and multiple users, which means that conflict in a global common is never unidimensional. For instance, ocean resources can simultaneously host consumptive conflicts that affect the fish population, excludable conflicts that affect access to water and/or negative externalities that affect pollution levels. The complexity of these situations indicate that problems of collective action in transnational commons go beyond recognised dilemmas of collective provision and span from defection problems to distribution and

[15] As indicated in supra note 7, this thesis adopts the definition of global commons put forward by Holzinger (2008). According to Holzinger, global common goods can be interpreted as a type or “subset of transnational common goods” (2008: 165).

disagreement problems[16] (Holzinger 2008: 153-159). Moreover, most of these conflicts occur at levels other than where their solutions are generally negotiated. Several studies reveal that most of these problems occur at individual, local or regional level, where access and use of the resource normally occur (Agrawal and Perrin 2009, Ostrom 2009). However, rule systems for these resources have generally been negotiated among state actors at international level and, as a result, disagreement over sustainable institutions has been presented as the ultimate example of defection or sub-optimal coordination. In this context, the complexity of conflict in transnational commons is not fully accounted for by rational choice models of collective action among state actors at the international level. Instead, tiered conflicts in global commons require refocusing analytical lenses at the level of the individual user of the resource where access and use take place (Ostrom 2010).

In order to correct the focus on state actors at international level, scholars examining collective action in global commons have proposed a polycentric approach to the study of institutions. This approach acknowledges that choices regarding the production, coordination, monitoring and enforcement of institutional arrangements can be achieved at autonomous and diverse levels of decision-making (McGinnis 2011, V. Ostrom 1999, V. Ostrom et al 1961). Essentially, proponents of polycentric governance noted that public economies are themselves organised in a decentralised and dynamic manner by which “many elements are capable of making mutual adjustments for ordering their relationships with one another within a general system of rules where each element acts with independence of other elements” (V. Ostrom 1999: 57, V. Ostrom et al 1961). Following from these findings, the absence of hierarchical order in international systems of governance does not imply the absence of (optimal) distribution of authority, just as the presence of a government with authority in its jurisdiction does not imply the hierarchical imposition of rules (Keohane and Ostrom 1995: 11). If, as V. Ostrom noted, polycentric orders apply to most social interactions, then it is crucial to identify

[16] Holzinger (2008) has created a typology of problems of collective action in transnational common goods. These include: typical defection problems resulting from prisoner’s dilemmas games, coordination problems resulting from assurance games, distribution problems resulting from rambo games (where coordination in achieved, but a suboptimal outcome can result from it) as well as disagreement problems resulting from chicken or battle of the sexes games (2008: 154). The modeling of these games reveals that the situations in which institutional arrangements are provided as common goods can vary considerably and, subsequently, can inform strategic actions in different ways, leading to different problems of collective action.

the distribution of rule-making, rule-monitoring and rule-enforcement in autonomous yet interdependent levels of authority in transnational commons (V. Ostrom 1999). As V. Ostrom explained, “systems of governance occur wherever complementary arrangements for formulating, using, monitoring, judging and enforcing rules exist” (V. Ostrom 2014: 46).

Polycentricity in global governance has been documented in social science by the literature concerned with the making, monitoring and enforcement of complex transnational regulation. This approach has been successfully applied to the study of international standardisation (Abbott and Snidal 2011, Mattli 2001, Buthe and Mattli 2011, Werle 2001) and (self)-regulation in global regimes (Haufler 2001, Mattli and Woods 2009), but has been less systematically transposed onto the analysis of governance in transnational commons (Cafaggi 2012b, Holzinger 2008). In this context, the benefits of the literature on global regimes, international standardisation and transnational private regulation are essential for the study of the global commons. First, they confirm the diversity of non-state actors involved in the development of global regimes, such as firms, NGOs, technical experts and epistemic communities operating outside national regulatory frameworks (Haufler 2001, Abbott and Snidal 2011). Second, they confirm the role of non-state actors in the monitoring and enforcement of global governance, rather than simply at the rule-making level (Cafaggi 2012a, Scott 2012). Third, they confirm the complexity of authority in networked governance and the emergence of the state as “a rule-taker as opposed to a rule maker” (Braithwaite in Cafaggi 2011:21, Buthe and Mattli 2011, Scott 2010, Werle 2001).

In particular, the literature on transnational private regulation can make a valuable contribution to the analysis of regulatory regimes in global commons because it allows for the recognition of diverse authority in the appropriation, provision and maintenance of shared resources (Abbott 2012, Abbott and Snidal 2009, Hoffman 2013). In addition, the analysis of transnational private regulation allows for the recognition of a diversity of entities with “jurisdictional integrity”, which are not always factored into the analysis of regulatory regimes in natural commons of a transnational nature (Skelcher 2005: 91). This literature acknowledges the legitimacy of club entities (Hooghe and Marks 2003), agency entities (Coen and Thatcher 2005) and polity entities (Jakobsen 2000) in defining, monitoring and enforcing rules in transnational systems of governance (Skelcher 2005). Lastly, the analysis of transnational private regulation allows for the recognition of a variety of models "engaging businesses, association of firms and NGOs, sometimes in hybrid form and often including governmental actors" in contemporary systems of governance (Scott, Cafaggi and Senden 2011: 3). This hybrid mix of actors is also mirrored in hybrid institutional arrangements utilised for the production, maintenance and preservation of transnational commons (Hess and Ostrom 2005). German and Keeler (2010) argue that contemporary natural resource management is increasingly governed by such hybrid institutions, which "do not fall within neatly inscribed units or categories of resource ownership or governance, but are characterised rather by their interdependence" (German and Keeler 2010: 572). This position brings benefits to the study of institutional arrangements in the global commons because it negates dichotomies such as market versus state authority, horizontal versus hierarchical structures and/or private versus public ownership as alternative modes of governance. This point is discussed in more detail in the next section, which considers whether property systems evolve from a specific distribution of authority or whether hybrid property arrangements can evolve in the governance of transnational commons.

1.1.4 How to fix problems of collective action in shared resources

In her study of the global commons, S. Buck offered a definition of common pool resources that shows the centrality of property systems vis-à-vis (problems of) collective action in the commons: "Common pool resources are subtractable resources managed under a property regime in which a legally defined user pool cannot be efficiently excluded from the resource domain" (Buck 1998: 5). Following this definition, the property regime that evolves from the open access nature of a common pool resource could lead to sub-optimal levels of consumption, maintenance and preservation of the common pool. Hence, it is relevant to explore how property arrangements are defined in common pools in order to evaluate their short or long term sustainability. There are, however, two main concerns regarding the models used to describe and prescribe property solutions in natural common pools, be they local or global. The first issue concerns the conceptual relationship between types of goods, types of owners and types of rights in general (German and Keeler 2010, McKean 2000) and the second issue concerns the definition of property rights with particular reference to common pool resources (Cole and Ostrom 2012, Schlager and Ostrom 1992).

The first issue concerns the discrete definition of property systems in common pool resources as private, common or public. As Cole and Ostrom (2012) noted, this categorisation has roots in Roman law definitions of property as *res nullius* (open access), *res communes* (common property), *res publica* (public property) and *res privatae* (private property). The issue of concern is not that the conceptualisation refers to discrete forms of property per se but that, although known to be referring to ideal types of property, this conceptualisation is still presented in normative debates in order to inform reforms of rule systems (Dagan and Heller 2001). This approach is restrictive because it associates types of rights to particular types of rights holders, i.e. public ownership (state), common ownership (collectivities) and private ownership (individuals). As noted by German and Keeler (2010), this approach can lead to problematic conclusions that only certain types of rights owners can successfully hold certain types of rights (German and Keeler 2010: 574). Scholars of institutional analysis in common pool resources have previously reported this conceptual limitation. McKean (2000) noted that:

> "the confusion of the publicness and privateness of <u>goods</u> (a natural given), <u>rights</u> (an institutional invention) and <u>owners of rights</u> (entities that make different representational claims) has led to serious errors (McKean 2000: 32, emphasis in the original).

McKean (2000) noted that, in particular, confusions between goods and rights have sometimes led to prescriptions of public rights in private goods and private rights in public or commons goods, just as confusions between owners and rights have sometimes led to conclusions that private entities hold private rights and public entities hold public rights, "when in fact public rights (rights to access and use that do not include the right to exclude others from such use) are generally held by private entities because public bodies have created such rights for citizens" (McKean 2000: 31-34). McKean's description of the relationship between goods, rights and owners of rights is valuable not only because it shows that any combination of goods, property rights and rights holders can exist, at least theoretically (McKean 2000: 33). McKean's description is essential because it reinforces evidence about the complexity of property arrangements in the commons, which take the form of "mixed regimes including elements of individual and common property" (Pennington 2012: 30).

This complexity of ownership arrangements brings the discussion to the second limitation concerning the definition of property rights in common pool resources. According to Schlager and Ostrom (1992), property arrangements in common pool resources describe not only the property entitlement, but also the rules used to create and enforce those entitlements (1992: 249). Following this approach, property arrangements are bundles of rights that concern both operational entitlements of use and access to a resource as well as the collective choice actions that define and change these operational entitlements (Kiser and Ostrom 1982, Schlager and Ostrom 1992). Similarly, Buck (1998) explains that "the property right to a resource is not a single right but rather a bundle of rights, such as rights of access, exclusion, extraction or sale of the captured resource; the right to transfer one's right to a second person; and the right of inheritance" (Buck 1998: 3).

Table 1.2 Property Systems in Common Pool Resources

Property Right		**Description of Property Right**
Operational Rights	*Access*	The right to enter a resource, which can be achieved by permission from a recognised authority, by purchasing a right to enter or by inheriting a right to enter.
	Use	The right to withdraw, to harvest or to extract units from the system resource, and to potentially use them as input for other production activities.
Collective Choice Rights	*Management*	The right to regulate internal use patterns and transform the resource by making improvements or by developing a variety of infrastructures on it.
	Exclusion	The right to determine who will have an access right to the resource.
	Alienation	The right to sell or lease any of the rights above for a given period of time

Source: Based on Cole and Ostrom (2012), Schlager and Ostrom (1992)

Table 1.2 provides a description of property bundles in common pool resources following two categories of rights: a) operational rights concerning rights of access and rights of withdrawal; and b) collective choice rights concerning the management, exclusion and alienation[17] of the resource (Cole and Ostrom 2012, Schlager and Ostrom 1992). As Schlager and Ostrom (1992) noted, the distinction between rights at the

[17]This thesis does not focus on the process by which rights of alienation are defined. This is because the right of alienation is defined by public actors at state level, rather than at transnational or international level.

operational level and rights at the collective choice level can also be explained as "the difference between exercising a right and participating in the definition of future rights to be exercised. The authority to devise future operational-level rights is what makes collective-choice rights so powerful" (Schlager and Ostrom 1992: 251).

This categorisation of rights illustrates why labelling property arrangements in common pool resources as private, common or public can represent a barrier rather than an enabler for theory development. Considering the difference between goods, owners and rights described by McKean (2000), this categorisation of rights allows for a more suitable reclassification of rights holders as individuals, groups or governments (O Ostrom et al 1999: 279), bearing in mind that, at least theoretically, any of the specified rights holders can have any configuration of operational and/or collective choice entitlements. This approach helps understand why public entities can formulate rights of use or access to a common pool resource that lead to imperfections in the application, monitoring or enforcement of these rules by private groups of users (Feeny et al 1990: 8). Similarly, this approach helps understand why parcelling rights to individual rights holders by a government – i.e. individual exclusive rights provided by a public entity – can lead to costly monitoring and enforcement that overlook the possibility that private groups or organisations of individuals can hold and share private rights without parcelling use exclusively on an individual basis (McKean 2000: 31). In this circumstance, individual private rights allow for resource unit maximisation, but do not and cannot ensure protection against resource crowding or overexploitation (Feeny et al 1990: 6).

This circumstance also reveals the main misconceptions regarding the privateness of individual and group property. As McKean noted (2000), the privateness of a right refers to "the clarity, security and especially the exclusivity of the right" or, to be more exact, to a clear specification of the entitlements of the rights holder, the protection of these entitlements and the exclusivity of the entitlements to the rights holder as opposed to non-holders (McKean 2000: 28). Nowhere does it state that the privateness of a property right refers exclusively to an individual rights holder. Thus, the privateness of a property right refers just as much to individual rights holders as to common or group rights holders, because common or group property designates property that is held by a finite number of people who manage those rights and exclude outsiders (Dagan and Heller 2001).

In this circumstance:

> "a group of individuals might be a private owner that can share property rights and thus create a regime of common property rights for managing common pool goods" (McKean 2000: 32).

Then, resource user groups can define property systems that create common rights of use based on internally negotiated processes of withdrawal from the resource as well as private rights of access based on exclusion of outsiders. In addition, this property arrangement can be de jure ensured by the external authority of a public entity or de facto ensured by the internal authority of the private group entity. In short, this conceptualisation of the privateness and publicness of rights and rights holders allows for recognition of the complexity of governance in common pool resources that facilitates, rather than hinders, the study of the relationship between the common pool good, the bundle of property rights and the nature of property rights holders.

To conclude, this conceptualisation of the relationship between goods, property arrangements and property holders is suited to the analysis of institutional arrangements in global commons for three reasons. First, it recognises that the physical properties of the resource – as natural properties of the common pool good – are relevant in the selection of institutional arrangements in the resource because they frame initial levels of rivalry and excludability in the consumption of the good. Second, this conceptualisation recognises that the bundle of rights that makes up property arrangements in common goods take the form of hybrid institutions or mixed regimes of governance. German and Keeler (2012) have defined hybrid institutions as "institutional arrangements governing the interdependencies among discrete property holders and regimes, whether defined by structure (linkage among entities with jurisdiction over discrete property regimes) or modes of governance (balance between self-organisation and formal regulation as complementary instruments of governance)" (2012: 571). Therefore, this conceptualisation frees scholars from the confines of social order heuristics that collapse rights and rights holders into analytical boxes labelled "the community", "the market" or "the state" (Streeck and Schmitter 1985) and allows for more detailed investigation into the relationship between the bundle of rights and the publicness or privateness of these rights. Third, this conceptualisation recognises the diversity of rights holders that can define, monitor or enforce an institutional arrangement in the commons, which can lead to polycentric systems of governance that are both complex and sustainable in the long-term (recall *Table 1.1*). If one follows the definition of property arrangements in common pools as comprising a bundle of operational and collective choice rights (recall *Table 1.2*), then private and public rights holders can have different configurations of authority as makers and keepers of these rights, without associating authority in defining, monitoring or enforcing these rights with the publicness or privateness of the rights holder.

Overall, rather than focusing on public entities that hold exclusive authority in negotiating institutional arrangements for the global commons, such as state actors, one should focus on diverse entities holding both individual and group interests that might not always coincide, that might lead to complex bundles of operational rights of use and access to the common pool and that might lead to complex bundles of collective choice rights, which involve both public and private actors sharing authority in the definition, monitoring and enforcement of these rights.

Therefore, this thesis proposes to refocus our analytical lenses beyond the role of public actors in negotiating arrangements for governing transnational common pool resources. The diversity of operational and collective choice arrangements witnessed in local and global commons suggests that the rule-making, rule-monitoring and rule-enforcement go beyond explanations structured in public negotiations along national-international lines. The remainder of this chapter explores whether this diversity of operational and collective choice arrangements is indeed witnessed in the early governance of the electromagnetic radio spectrum as an example of a transnational common pool resource. Overall, the following sections find tensions between the publicness and privateness of these property arrangements in the early governance of the radio resource. Thus, the diversity of these property arrangements require a closer study of the role of individual private users and associations of private users in defining the bundle of rights that make up institutional arrangements in transnational commons.

1.2 The Radio Spectrum as a Transnational Common Pool Resource

The electromagnetic radio spectrum has been previously recognised as a transnational common pool resource (Herter 1985, Hess 2008, Soroos 1982, Wijkman 1982). Representing the totality of radio frequencies, the radio spectrum is exposed to problems of collective action resulting from the competitive withdrawal of resource units by users, which reduces resource availability for others (i.e. rivalry of consumption), as well as from the difficulty of excluding beneficiaries that do not invest in costly cooperation for the provision of stable institutions of governance (i.e. non-excludability).

The sections below start by introducing the natural properties of the radio spectrum resource. As E. Ostrom noted, every common pool resource has different physical properties, which frame different incentive structures for actors drawing benefits from their use (Ostrom 1990, 2010). Thereafter, the sections outline three main problems of collective action in the radio spectrum resource: a) the problem of interference, as a type of negative externality or pollution resulting from the activity of providing wireless communications on the radio resource; b) the problem of private control over a common resource utilised to deliver a public good – i.e. communications - as a type of tension between the exclusive right to use the radio resource and the universal right to public correspondence; and c) the problem of non-interconnection between devices and non-intercommunication between services operating in the radio resource, as a type of tension between exclusive and non-exclusive property on the resource. These tensions reveal the complexity of problems of collective action in transnational commons, which span from coordination problems in situations of externalities arising from the consumption of radio frequencies to distributional problems in situations of rival consumption of radio frequencies by public and private actors.

Overall, the following sections reveal the presence of both public and private industry actors in defining and redefining operational and collective choice rights in the radio spectrum. This account of early coordination identifies the presence of private actors, sometimes grouped in strategic associations, in rule-making for managing radio frequencies as well as their position in relation to the public actors present in the process. The main evidence to support the central position of industrial actors in early rule-making is the decision to parcel out international radio frequencies by communications service rather than by sovereign state. This decision, in place to the present day, dates back to the early 1900s when the first institutional arrangements for governing the radio resource were established. This decision also reveals how distributional problems resulting from access to radio frequencies, externality problems resulting from use of radio frequencies as well as congestion problems resulting from difficulties of exclusion in the radio resource were framed by negotiations between private actors on the one hand and between private actors and public actors on the other hand. Bringing these issues into contemporary debates about how the radio resource should be apportioned and should be allocated to a growing number of wireless communications services, the chapter concludes that the radio spectrum is a suitable case to test the relevance of private venues of collaboration and contestation in determining property arrangements in transnational common pools.

1.2.1 The Three I's –interference, intellectual property and interconnection

Wireless communications via radio frequency waves were first discovered in the mid to late 19th century and gained immediate acceptance as alternative to wired telegraph communications due to their strategic value in commerce and defence. However, the borderless and open access nature of the radio spectrum resource raised questions about how wireless communications should be managed in a global system organised in empires. In this context, three main problems of collective action came to structure transnational negotiations over radio spectrum management. First, the issue of harmful interference as a negative externality produced by communication devices using this open access resource concomitantly. Second, the issue of establishing intellectual property rights on the first technology solutions for producing and delivering wireless communications as a form of exclusive use of this open access resource. Third, the issue of interconnection between proprietary communications systems competing for access on the radio waves, as a form of mitigating attempts to restrict access for private use. Since the Preliminary Conference on Wireless Telegraphy of 1903, these issues have been at the core of national, transnational and international negotiations. Their dynamics have framed positions of rivalry and excludability on the radio resource, not only between private actors as initial providers of the technology that facilitated the extraction of economic value from this resource, but also between private and public actors involved in defining property arrangements in the resource.

Communications via electromagnetic radio frequencies came into application in the mid to late 19th century, against an international context dominated by Great Power politics. This was an age characterised by the globalisation of commerce via intensive maritime traffic, the globalisation of communications via widespread telegraph cables and, as a result, the emergence of commercial champions with international operations across political empires. Wireless communications are largely associated with Guglielmo

Marconi who invented, patented and commercialised the first devices to transmit information via electromagnetic waves using the internationally standardised Morse code[18].

Wireless communications developed against a background of established international cooperation over the communications system of cable telegraphy that stretched across the globe. On the one hand, the international system of cable telegraphy followed closely the organisation of empire and reflected investments made by the Great Powers in the telecommunications infrastructure that later consolidated the position of Post, Telegraph and Telephone authorities (PTTs) as well as the commercial capacity of national champions in manufacturing communications equipment (Headrick 1991, Hills 2002, Hills 2007, Tomlinson 1945). On the other hand, the international system of cable telegraphy raised a number of coordination problems over the flow, pricing and operability of communication services in this complex network of cables, which led to the creation of the International Telegraph Union in 1865[19] (Codding 1995, Griset 1992, Headrick 1991, Hills 2002). The structure of coordination under the International Telegraph Union, the predecessor of the contemporary International Telecommunications Union (ITU), maintained responsibility over the telegraph network in the hands of governments and established an international bureau with responsibility to centralise and monitor changes to national networks with potential technical and/or commercial impact on the wider international communications system[20] (Cowhey 1990, Genschel and Werle 1993). Wireless communications using radio frequencies developed against this background of international coordination in cable telecommunications that, most importantly, established governments as central in

[18] Against popular belief, Guglielmo Marconi is not the inventor of radio. As Headrick noted, “his contribution consisted in putting together pieces attributed to other men – Hertz’s spark, Branly’s coherer, Popov’s antenna, Lodge’s tuning circuit […]” (1991: 117). However, Alekdandr Popov called Marconi “the father of wireless” for developing the practical application of wireless using the standardised means of communications through Morse code, as used in cable telegraphy (Simons 1996: 37).

[19] The first International Telegraph Conference was called by the German Empire in 1865 and was addressed to all interested parties across the European continent. The signatories of the convention were the representatives of: Austria, Hungary and Boehme, Bade, Bevier, Belgium, Denmark, Spain, France, Greece, Hamburg, Hanover, Italy, Netherlands, Portugal and Algarve, Prussia, Russia, Saxony, Sweden and Norway, Swiss Confederation, Turkish and Wurttemberg (ITC 1865).

[20] It should be noted that, since its inception, the ITU and the ITU Conferences have been open to private companies and organisations, although these entities participate on a consultative basis and do not have the right to vote in Regulations or Treaties.

delivering and administering telecommunications as a public good[21], derived from "the right of all people to access correspondence by means of international telegraph" (ITC 1865, Art 4). As outlined below, it is this approach to communications as a public service that came to challenge the first use of radio waves on an exclusive basis for the delivery of wireless communications by a private industrial actor.

In this age of empire, wireless communications received immediate attention for their value in ship-to-shore and ship-to-ship communications in the context of the globalisation of commerce of the early 20th century. Increased mobility was thus a valuable attribute of communications using radio waves. However, compared with the wired network, wireless telegraphy raised a different coordination problem – that of managing interference between services operating internationally. Because radio frequencies travel across national borders, wireless communications cannot be controlled outside the territory they are emitted from and, as a result, are susceptible to interference from other communication services they meet along the way. As a type of electromagnetic disturbance, which occurs when the use of some electrical equipment obstructs or degrades the performance of another, interference is thus a type of pollution on the radio spectrum resource. As a result, the first aspect of international cooperation in wireless communications was the issue of interference between communication services delivered, largely, by private or public entities registered within the territory of the signatories of the International Telegraph Convention (1865). As a negative externality, interference affected the very quality and secrecy of wireless communications, reducing the utility derived from licensed services. Thus, the Preliminary Conference on Wireless Telegraphy in Berlin[22] (1903) introduced the principle of non-interference, by which "the working of wireless telegraph stations must be organised, as far as possible, in such a manner as not to interfere with the working of other stations" (Art V). However, against the background of resolving the problem of interference, the first international negotiations in radiotelegraphy were framed by

[21] Art 4 of the International Telegraph Convention of 1865 stipulated that "the contracting parties recognised the right of all people to access correspondence by means of international telegraph" (ITC 1865).

[22] Once again, the German Empire made the call for this international conference. As it will be outlined below, one of the main reasons for calling an international conference in radiocommunications stemmed from the threat of exclusivity in the radio waves imposed by Marconi.

tensions, both at national and international level, between the private and public control of the radio spectrum.

With virtual unanimity in the specialist literature, the rapid growth of wireless communications in various areas of economic activity is associated with the work of Guglielmo Marconi and, particularly, his attempt at the creation of a proprietary global standard for wireless telegraphy in the early 20th century (Headrick 1991, Hills 2002). Marconi achieved this position by establishing intellectual property rights on the first devices used for commercial wireless communications. The dynamics of contestation that resulted from Marconi's attempt at a de facto monopoly over wireless communications is thus crucial for understanding the nature of collective action that has defined transnational radio spectrum management since its inception to the present day. Not only do these dynamics help us understand the relationship between private and public actors in managing global commons, but they also facilitate a closer look at the relationship between industry actors involved in technological innovation and knowledge exchanges in the sector of wireless communications.

In 1896, Marconi filed a patent for his invention in Britain and, a year later, set up the Wireless Telegraph and Signal Company Ltd to take over all past, present and future patents developed under his name[23] (Simons 1996: 44, Tomlinson 1945: 11). Registered as Patent 12039, the claim read: "I believe that I am the first to discover and use any practical means for effective telegraphic transmission and intelligible reception of signals produced by artificially-formed Hertz oscillations" (Simons 1996: 44). Soon, Marconi's patent received the interest of the British Post Office. However, the relationship between Marconi and the Post Office reached an immediate standstill when Marconi rejected their offer to purchase his patents. Regarding the Post Office as direct competitor, Marconi leased equipment to ship owners and transmitted free of charge on claims of intercompany communications, which bypassed the monopoly service of the Post Office on all communications. Soon after, Marconi won several contracts with the

[23] G. Marconi moved to Britain in 1986, following a lack of interest in his equipment for wireless communications by the Italian Ministry of Posts and Telegraph (Headrick 1991: 117, Hill 2002: 94, Simons 1996). At the time, the Italian government advised Marconi to make his invention available worldwide without a patent, since Marconi had not made a new discovery in telegraphic transmission via radio frequencies but, in reality, created a practical device for the stable transmission and reception of signals using previous scientific discoveries (Simons 1996: 44). However, Marconi proceeded to patent his invention in Britain.

British Admiralty and Lloyd's of London, and introduced a policy of non-intercommunication on all services provided for commercial maritime purposes.

Marconi's policy of non-interconnection/ non-intercommunication meant that any ship wanting to communicate with another one insured by Lloyd's would have to purchase or rent Marconi equipment (Headrick 1991: 119). This position prompted Marconi to make new claims to change his company's status from an international supplier of wireless communications equipment to an international operator for the general public, by setting interconnection at a surcharge between his service and domestic ones, such as those provided by the Post Office (Hills 2002: 97). As Jolly and Hills noted, Marconi's argument in support of this de facto monopoly was based on the requirement to control interference in order to deliver quality of service in ship-to-ship and ship-to-shore transmissions (Hills 2002: 97, Jolly 1972: 137). In fact, throughout the first five years of existence, Marconi's company made intellectual property claims on all improvements of the technology under Patent 12039, creating a considerable portfolio in short-range and long-range wireless communications and taking a consistent position in filing for patent infringements in most countries where Marconi subsidiaries were operating (Simons 1996). The production of proprietary equipment, coupled with the adoption of a policy of non-intercommunication in service delivery, indicates Marconi's interest to establish exclusive use of international radio frequencies. As Headrick noted "Marconi, never modest in his ambitions, wished to claim the electromagnetic spectrum as his private domain and create, in radio communications, a company as powerful as the Eastern group in cables" (Headrick 1991: 119).

Thus, Marconi's attempt to establish a private monopoly on wireless communications came in direct contradiction with the role of governments to ensure "the right of all people to public correspondence", as stipulated in the International Telegraph Convention (ITC 1865, Art 4). In addition, Marconi's de facto monopoly on wireless communications had also reconfigured the interests of competitors affected by Marconi's imposition of a surcharge for international communication services. For instance, in 1897, the German Emperor's Scientific Advisor – A. Slaby – attempted to set up a commercial agreement between Marconi and AEG[24] of Germany for the common provision of transnational wireless communication services. Failure to reach

[24] At the time, AEG was one of the most established manufacturers of telegraph systems in Germany, also benefiting from worldwide orders.

an agreement led to the creation of Telefunken in 1903, one of the main competitors to Marconi in the coming years[25] (Simons 1996: 47).

In 1903, the year of the creation of Telefunken, the German government proposed the first international conference for coordinating wireless communications. Commenting on the reasons behind this initiative, Tomlinson noted:

> "It was perhaps more in view of the imminent stranglehold of the Marconi interests in wireless communications, than the actual need for international regulation of these communications, which inspired the German Government to take initiative in organising the first international conference on wireless telegraphy" (Tomlinson 1945: 13).

Unsurprisingly, at the conference, the German delegation proposed free interconnection as a fundamental principle in international wireless communications. Hills noted that, put simply, the goal of the German manufacturer, backed by the state, was to compel Marconi to share his network with their equipment by enforcing free interconnection and global standardisation of devices by international treaty (Hills 2002: 101). Thus, compulsory interconnection was perceived, by a majority of conference participants, as a means to limit Marconi's position in the market for wireless communications as derived from his first mover advantage in the radio resource. Because compulsory intercommunication did not receive the support of all members at the first wireless telegraph conference[26], the issue was pursued at the International Radiotelegraph Conference of 1906.

This time, the German delegation changed its approach. Citing interference between a growing number of services – a recognised problem at the time of the conference[27] – the German delegation proposed the introduction of service regulations for all ship-to-shore transmission, whereby services delivered by public entities would be registered in

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[25] The Telefunken system did not infringe on Marconi's patents because both Siemens and AEG had strong patent portfolios in wired telegraphy and, with the help of A. Slaby, were able to branch into wireless telegraphy soon after Marconi's inventions.

[26] The Italian and British delegations did not support the clause, citing contracts with Marconi (Hills 2002: 102).

[27] Commenting on the nature of international communications at the time, Tomlinson (1945) noted: "In spite of technical progress and the greater number of radio stations in operation, the air was still legally free. While the conditions of operation were established in certain countries by national legislation, the effective use of radio as a form of international communication, especially in the areas where maritime traffic was heavy, depended on the good will of neighbouring stations. All too frequently, good will was lacking" (Tomlinson 1945: 18).

different frequency blocks than those delivered by commercial entities. Thus, the proposed solution to avoid interference and crowding of certain frequency bands was to designate government services, including military services, to higher frequencies (600kc/s-1,600kc/s), while designating commercial services to lower frequencies (300kc/s-600kc/s)[28].

The effect of this measure was, essentially, the reconfiguration of rivalry and excludability in the radio spectrum. At the time, Marconi's most successful ship-to-shore communications service over long distances was operating in higher frequencies, above 600kc/s. Being a private and commercial service for the shipping industry, Marconi's international operations were essentially squeezed out of the radio bands above 600kc/s, which became designated, exclusively, to government services. This favoured Telefunken, whose equipment was deployed on all state-owned German vessels, which essentially qualified them for access in the over 600kc/s frequency bands. By adopting this service-based regulation for international wireless communications, the private control established by Marconi in longwave communications was essentially eliminated. The allocation of radio frequencies by communications service, coupled with the principle of non-interference and the principle of interconnection, form the basic regulation of the transnational radio resource to the present day.

These regulatory measures had a clear impact on changing the dynamics of rivalry in the radio spectrum. They altered the incentives structure for both public and private actors drawing economic benefits from the radio resource. For instance, relations between public and private actors at the national level had altered soon after the Berlin Conference of 1906, when the British Post Office signed a new licensing agreement with Marconi based on financial incentives, rather than punitive measures aimed at restricting his operations, in return for accessing frequency bands otherwise closed for commercial use (Headrick 1991: 125, Hills 2002: 131). Commercial relations between industrial actors had also changed, when Marconi and Telefunken agreed to form a patent pool in 1911, which gave the two companies access to highly proprietary knowledge in long distance broadcasting (i.e. long distance fixed point

[28] Kc/s stands for "kilo cycles per second", a measure established by Hertz for recording the frequency of an electromagnetic wave. Later, the measure of "kilo cycles per second" was replaced by Hz, showing the importance of the discovery.

communications) and led the two companies to establish a new monopoly in frequency bands yet unregulated by international treaty.

Overall, the early history of radio spectrum management reveals tensions between government and commercial control of the wireless resource. This early history shows the private origin of wireless communications as well as the clear reliance on technology for extracting value and for establishing property systems in a transnational resource (Ostrom in Buck 1998: xiii). This early history also reveals that both public and private actors have strong incentives to set preferable rules in the radio spectrum, rules that can alter the degree of rivalry and excludability in the radio pool, triggering a reorganisation of the resource and producing new incentives for contestation and coordination. Therefore, this early history reveals the centrality of distributional and coordination problems of collective action in the radio resource. On the one hand, distributional problems informed dynamics of contestation regarding rivalry and excludability between private and public users of the resource. On the other hand, coordination problems informed dynamics of coordination regarding the proprietary technologies used to extract economic value from the radio resource. The next section addresses how these dynamics of contestation and coordination inform positions of authority in setting property arrangements concerning rivalry and exclusion in the transnational radio spectrum pool.

1.2.2 Who fixes problems of collective action in the radio spectrum

Describing the governance of the radio spectrum, Buck noted that:

> "The radio spectrum is res communes [common property], rather than res nullius [open access] because allocation of the spectrum to various users is not permanent. Users receive usufructuary rights rather than a full bundle of proprietary rights" (Buck 1998: 154).

This description of the property arrangements established on the radio resource, although conceptually misleading[29], is relevant for two reasons. First, it informs about the nature of operational ownership on the radio resource. Second, and most importantly, it informs about the nature of collective choice rights on the radio resource

[29] Based on the categorisation of property rights presented in *Table 1.2* above, usufructuary rights are, in fact, the essence of the bundle of property rights in a common pool resource, referring to both operational rights of use and collective choice rights to exclude users from accessing the resource.

– i.e. the rights of management and exclusion of property negotiated in the resource (revisit *Table 1.2*). Practically, what Buck is proposing is that property rights on the radio resource, as in most global commons, cannot and should not be interpreted in the categorical sense we interpret most individual ownership. Chaduc and Pogorel (2008) noted that the question "who owns the spectrum?" has "no answer and almost no sense" (2008: 71). When making this proposition, the authors were probably considering individual ownership. In fact, the Constitution of the International Telecommunications Union recognises "the sovereign right of each state to regulate its telecommunications" but does not make explicit reference to property rights in the radio resource (ITU 2011, Art 1). This entails that public actors such as governments have the right to regulate the output derived from the use of the radio resource – i.e. wireless communications – rather than an explicit and exclusive collective choice right to manage the radio resource. This approach sheds a different light on contemporary debates about individual and government property on the radio spectrum and shows the practical reality that property arrangements are best understood in relation to positions of authority in defining the degree of rivalry and excludability in the resource. Thus, the question of property is directly linked to the question of authority over who defines and redefines rivalry and excludability in the resource.

E. Ostrom showed that the term common-pool resource "refers to a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom 1990: 30). A closer look at the early history of radio spectrum reveals that, when Marconi developed the technology to appropriate radio waves for wireless communications, the spectrum was an open access resource with no established operational rights, similar to the earth's oceans or atmosphere in a state of nature (Herter 1985). This made radio spectrum prone to increased rivalry of consumption as well as increased difficulty in excluding multiple users (Aral 2009: 687, Ostrom et al 1999: 278). Consumption in the radio spectrum is highly rivalrous because, when used for the production of wireless communications, radio frequencies are essentially removed from the available pool. When these frequencies are used intensively, overcrowding can occur, leading to frequency scarcity. As Wormbs noted, crowding in the radio spectrum "is peculiar since it takes place both in a geographical dimension with transmitters close in space, and in a frequency dimension with [services] on adjacent frequencies in the electromagnetic spectrum" (Wormbs 2011: 93). Because of these two dimensions of geography and frequency, radio signals can spill over both into the "area dimension" – because they travel through space – and into the "frequency dimension" – because their emission can overflow out-of-band (Vany et al 1969: 1515). These effects of rivalry in consumption were recognised in the early stage of wireless communications, as the number of service providers of wireless communications increased in different radio bands, highlighting the subtractive and finite nature of the resource in conditions of use[30] (Wade 1987: 96). Similarly, the difficulty of excluding others from using the radio resource was also recognised early on, when Marconi's attempt at establishing a private monopoly in certain frequency bands could not preclude both public and commercial entities from using the radio resource.

This situation highlights the importance of property arrangements that order relationships of rivalry and excludability in the radio pool, so that stable economic value can be derived from the resource in the absence of pollution as a result of interference and in the absence of free-riding on the networks of others, which can lead to overcrowding[31]. In this context, basic coordination in defining a set of rules that prevent interference and encourage interconnection is desirable for both public and private actors extracting economic value from the radio resource. However, these basic rules that internalise negative externalities do not solve distributional problems of rivalry and excludability[32]. This places the question of authority in defining operational rights of

[30] However, in radio spectrum, rivalry of consumption and difficulty of exclusion do not lead to the permanent contamination or depletion of the resource (Wormbs 2011: 106). These properties entail that, compared with other natural resources such as the air, water or minerals, the radio spectrum returns to its original state, at no cost, once all users have been removed from it. However, radio spectrum is predisposed to congestion, which Friedman considered as having the same impact on the residual supply of the resource as depletion. Using the example of fish and petroleum as resources that can be affected by depletion of supply, and highways and radio waves as resources that can be affected by congestion of supply, Friedman argued that exhaustion of usable supply occurs in both types of resources and "therefore the resources are appropriately called 'exhaustible'" (Friedman 1970: 856-857).

[31] Blomquist and Ostrom showed that these characteristics do not always lead to dilemmas of the commons. A commons dilemma occurs only when overuse, erosion or deterioration of the resource prevents the ability to continue to provide the value 'use-units' (1985: 383).

[32] Distributional problems of collective action occur because resource users can disagree with regard to which of the multiple efficient equilibria they prefer in order to define the degree of rivalry and excludability in the resource pool, see for instance Holzinger (2008) and Martin (1995).

access and use at the core of dynamics of contestation and coordination between resource users. The next section provides evidence of these dynamics of authority in setting operational rights in frequency bands designated for broadcasting services across Europe, as negotiated between private and public actors in the mid 1900s.

1.2.3 Where to fix problems of collective action in the radio spectrum

In the interwar period, a growing number of radiotelegraph services, using both short wave and long wave frequencies, started populating the international radio spectrum[33]. Some of these services such as ship-to-ship and ship-to-shore communications were regulated by international treaty, generally specifying the power levels they could operate at in order to prevent harmful interference within and between frequencies. Other services such fixed point communications – i.e. broadcasting – were not regulated by international treaty prior to World War I. These services were not regulated internationally because technological knowledge for long distance broadcasting was ring-fenced in patent pools established by Marconi and Telefunken since 1911 (Hugill 1999: 100). However, amateur broadcasting services were also operating in shorter distances, increasingly overcrowding frequencies. This situation was dealt with differently in the United States and across the European continent, where a large proportion of broadcasting stations were registered. As opposed to the United States, European administrations established broadcasting as a public service and, essentially, created a public network of stations across each of their territories. Whereas this measure controlled overcrowding and facilitated content monitoring, it also led to increasing the transmission power of broadcasting stations, which were interfering across borders. The problem of broadcasting interference became most endemic on the European continent in the interwar period. The problem originated, at least in part, from the fact that transnational radio frequencies were "parcelled out" by communications service rather than by sovereign state (revisit *Section 1.2.1*).

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[33] During this time, it was discovered that not only long waves could carry communications over long distances. Marconi experimented with short waves and, as Headrick noted, he made a second contribution to wireless communication by showing that short waves are as suitable to deliver long distance communications as long waves (Headrick 1991: 202-203). It should be noted that, due to the curvature of the earth, short waves have higher frequencies whereas long waves have lower frequencies. These physical properties make them more suitable for different types of communications.

As a result, public actors proposed to redesign the rule of international allocation of radio frequencies from service-based to state-based at the International Radiotelegraph Conference (IRC) of 1927 in Washington. Commenting on the proceedings of the Conference, Codding and Rutkowski (1982) noted: “the most thorny question then, as today, concerned the kind of administrative scheme that should be adopted for vesting rights in frequency usage” (1982: 15). However, the Radio Regulations of the IRC (1927) did not achieve a change in the allocation of international frequencies from service-based to state-based. Instead, the Radio Regulations (1927) maintained allocations by communications service and “parcelled out” the radio spectrum in two geographical regions across the world – the European region and the rest of the world (IRC 1927). Essentially, this confined the problem of interference in broadcasting to its original source – i.e. Europe – without altering the international rules of frequency allocation by communications service.

The architects of this rule change were not the public signatories of regulations, but the private industrial actors present at the conference. Citing the US Assistant Secretary of State present at the IRC (1927), Hills shows that “the radio companies practically wrote it [the IRC Convention]” (Hills 2002: 202). These radio companies were the British Marconi Company, Telefunken, Companie Generale de T.S.F. and Radio Corporation of America. In 1922, following a rapid increase in their operations in the unregulated long wave bands for broadcasting, they set up an international wireless consortium known as the Commercial Radio International Committee (Headrick 1991: 185, Hills 2002: 196, Tomlinson 1945: 57). This association was not only a patent pool but also a traffic agreement between the four companies, effective until 1945. The effect of this agreement was not only their “undisputed control […] of the production of wireless apparatus” (Tomlinson 1945: 57) or even the “cartelisation of the worldwide production of wireless equipment” (Hills 2002: 196). The most important aspect of the agreement was the traffic arrangement between them, which essentially led to their joint allocation of long wave frequencies for international broadcasting. This arrangement was, essentially, an exclusive private regime for the allocation of transnational radio frequencies for broadcasting services that ran in parallel to national services. In this context, the proposal to allocate international frequencies by state rather than by service was unacceptable for the ‘Big Four’ (Tomlinson 1945: 57). This rule change would have squeezed them out of the long distance broadcasting bands, similar to the way

Marconi was squeezed out of the over 600Kc/s bands in the early 1900s (revisit *Section 1.2.1*). Thus, the position of the 'Big Four' explains why long distance broadcasting was not regulated by international treaty at the IRC (1917), maintaining their exclusive use of these bands. Their position also explains why the allocation of radio frequencies was maintained by communications service rather than by state and why geographic parcelisation was introduced in order to contain the problem of interference and overcrowding of public broadcasting services in Europe, without altering the service-based regulation of international frequencies.

As a result, the problem of interference and overcrowding continued across Europe until the late 1930s, following several frequency plans negotiated by public service operators organised in what is now the European Broadcasting Union (1950-present). Since then, the radio spectrum has been reorganised in three geographical regions[34], each negotiating their own frequency plans. But the international allocation of radio frequencies is still achieved by communications service rather than by state. The example of the commercial agreement between the 'Big Four' reveals the authority private industrial actors have had in defining operational rights in transnational radio frequencies so as to reconfigure the rules of rivalry and exclusion among them as well as between them and public actors administering the radio waves. This also reveals that private international agreements concerning particular technology exchanges or technology pools are not only mechanisms of establishing positions of dominance in communications markets but also mechanisms of altering operational rights of use and access in the radio resource. As in the case of the 'Big Four', this is rarely achieved at national level where these actors are in fact licensed for operation, but at the transnational level where they can negotiate positions of rivalry in wider radio pool. In fact, the international parcelisation of radio frequencies by communications service, rather than by state, facilitates the formation of associations of private industrial actors for the extraction of economic benefit in wider than smaller radio pools. Hence the incentives to maintain the international regulation of radio frequencies by communications services. Before proceeding to explore similar dynamics in more depth in the case studies of this thesis, the next section outlines how the organisation of

[34] Art 43 of the ITU Constitution states that "Members States reserve the right to convene regional conferences, to make regional arrangements and to form regional organisations, for the purpose of settling telecommunication questions which are susceptible of being treated on a regional basis" (ITU 2011, Art 43).

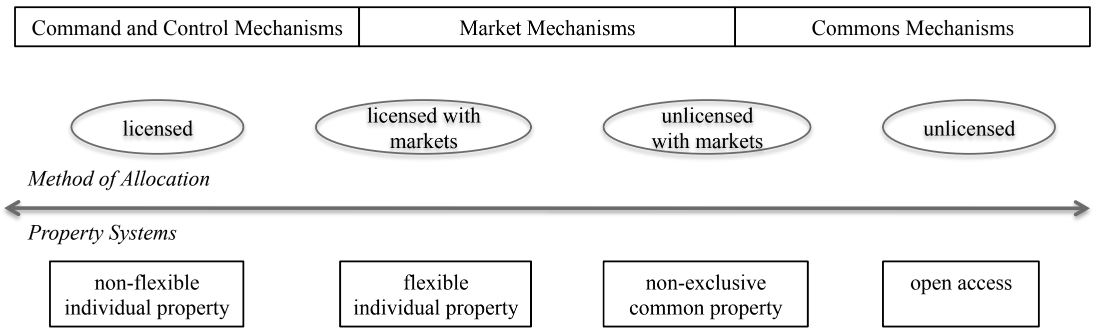
property arrangements in radio frequencies has been conceptualised in contemporary debates about the most efficient levels of rivalry and excludability in radio spectrum policy. Nevertheless, the growing focus on spectrum policy can miss out on important dynamics of contestation and coordination at the transnational level and, as a result, can paint an incomplete picture of the relationship between authority and property arrangements in the global radio common.

1.2.4 How to fix problems of collective action in the radio spectrum

The position of public actors as managers of radio frequencies at national level has focused attention on the policy mechanisms they hold to administer this resource. There is little doubt that, in most situations, public administrations still provide initial access to the radio resource, following mechanisms that resemble regulation by "command and control" (Brito 2006, Ogus 2004: 245-246). There is also little doubt that, recently, public administrations have introduced more flexible mechanisms of allocation that facilitate "secondary markets" or "unlicensed access", while maintaining different degrees of administrative control (Bauer 2002, Benkler 2002, Baumol and Robyn 2006, Faulhaber and Farber 2003, Huber 1998, Shelanski and Huber 1998). However, prescribing new mechanisms for spectrum policy can also be a limiting exercise because, in most cases, they concern only operational rules of access in the first instance and at state level. While relevant for understanding the rules-in-use at a given time, these approaches cannot fully capture rule change in the management of the spectrum resource and, particularly, change derived from elsewhere than the national level. Thus, the relationship between these mechanisms and the property arrangements they sometimes aim to create is not always straightforward.

From an analytical perspective, these mechanisms have been categorised in three broad types of regulatory regimes – administrative, market, commons – which rarely capture the full bundle of operational and collective choice property rights witnessed in common pool resources (revisit *Table 1.2*). These typologies carry an important limitation: the artificial pairing of broad regulatory regimes with particular spectrum allocation mechanisms and, in turn, with particular types of property (*Figure 1.1*). The debate around these three typologies is briefly presented below. Although they carry important considerations about the governance of the radio spectrum, they rarely consider the full bundle of property rights in common pool resources and, instead, focus mostly on the linkages between mechanism of allocating access and the derived rights of access.

Figure 1.1 Common Assumptions of the Relationship between Public Methods of Allocating Radio Waves and the Property Systems They Produce



Allocations by Command and Control Mechanisms. This procedure is recognised as the most widely used mechanism for allocating radio frequencies (Brito 2006). It has been promoted for simplifying the regulatory process and ensuring that wireless communications do not interfere with each other (Baldini 2013: 96). It has been largely associated with the issue of licenses by a communications authority charged with 'reducing chaos' in the radio waves. It has been regarded as the preferred method of allocation for incumbents because it provides non-flexible, individual rights to property in the form of non-transferable licenses, which in turn, protect investments in large-scale communications networks (*Figure 1.1*). However, this method has been criticised for leading to the politicisation, capture and, in the long term, inflexible distribution of the radio resource to users that might not always utilise it efficiently (Faulhaber and Farber 2003: 195-197). Thus, this method has been critiqued for being "vulnerable to influence costs" and leading to artificial scarcity by regulatory means (Coase 1959, Vany et al 1969, Lehr and Crowcroft 2005, Melody 1980). Faulhaber and Farber (2003) argue that the longevity of this regulatory regime, based upon non-flexible rights to property on the radio spectrum, is derived from the strong incentives incumbents have to keep the systems rather than to change it (2003: 195-197). The main limitation of this approach is that it suggests users of the radio spectrum will always have a preference for individual property rights when 'harvesting' the radio resource.

Allocations by Market Mechanisms. This approach, first introduced by economist R. Coase in relation with the administration of radio frequencies by the Federal Communications Commission in the United States, proposes replacing the allocation of radio waves by non-flexible individual property rights as established by the license system with flexible private property whereby owners could sell, subdivide and re-aggregate spectrum parcels. Coase noted that "once the rights of potential users have been determined […], the rearrangement of rights could be left to the market" (Coase 1959: 30). Coase suggested that, for spectrum allocations to be achieved efficiently, a regulatory regime for creating well-defined private property rights and the price mechanism would be sufficient to alleviate the spillovers of harmful interference and congestion. However, Coase's initial argument has been reformulated in current debates about spectrum policy to refer to a licensing regime still based upon individual property rights with the flexibility of trading the license in secondary markets (*Figure 1.1*, Vany et al 1969, Faulhaber and Farber 2003). This mechanism of allocation would then benefit from flexibility in the choice of technology or the choice of service. In addition, this type of market exchange is recognised to encourage innovation and to facilitate spectrum refarming, as frequency bands would shift uses more quickly. The price mechanism would then be sufficient to capture all the information about supply and demand (Faulhaber and Farber 2003: 199). The limitation of this approach is that the radio spectrum is still allocated on an individual basis and that licenses generally carry provisions established under the administrative system that limit their tradability on other bases such as technology or service specifications (Hazlett and Spitzer 2006, Lehr and Crowcroft 2005: 422).

Allocations by Commons Mechanisms. This approach is considered to have led to the establishment of spectrum commons. It has been largely attributed to unlicensed bands where devices have embedded 'politeness protocols' so that they don't interfere with each other. The successful operation of these devices in certain frequency bands led to question the necessity of establishing exclusive rights through licenses, reshaping the current understanding of harmful interference and secure investment (Brito 2006, Benkler 1999, Benkler 2012). Allocations by unlicensed/commons mechanisms are sometimes falsely associated with open access systems where property arrangements are minimal. In reality, unlicensed allocations of radio frequencies are highly regulated because they carry technical specifications – established by public or private administrators – regarding power levels and the general behaviour of unlicensed users in the band. In addition, the relationship between unlicensed/commons mechanisms and technological innovation or efficiency in the use of radio frequencies has been increasingly contested on grounds that innovation is rarely only the result of regulatory measures for providing open access onto the radio resource (Faulhaber and Farber 2003, Lehr and Crowcroft 2005: 422). As a result, property arrangements in unlicensed/commons bands are as complex as any other institutional arrangements that set specific levels of rivalry and excludability in a given frequency band.

These three mechanisms of allocation reveal a number of important considerations about the current debate in radio spectrum policy, confirming some of the analytical limitations identified by scholars studying property arrangements in common pool goods (Bromley et al 1992, McKean 2000, Pennington 2012). First, there is still considerable confusion about the definition of property systems as individual or collective rights of access rather than as the more complex bundle of operational and collective choice rights witnessed in the ownership structures of common pool goods. Second, there is still considerable reliance on the role of external actors such as regulatory agencies or governments on defining and re-defining rules about the degree of rivalry and excludability among direct resource users of a given frequency band. Third, there is still considerable focus on spectrum policies at the state level, with a considerable attention being paid to the relationship between public policies of allocating access and the efficiency of those rights of access in extracting value from the radio resource. As a result, the debate is too often structured around 'parcelling out' versus 'opening up' the radio spectrum as main options for defining property arrangements in this resource. Lastly, these mechanisms tend to view private resource users – such as communications service and system providers – as receivers of flexible or non-flexible property rights in the radio resource. However, the early governance of the radio spectrum reveals that private resource users are considerably more active in defining and re-defining rule systems in the radio resource than the debates about public mechanisms of allocating access to this resource would allow. The case of the 'Big Four' in the early 1920s provides a powerful example of the extent to which private industrial actors can collectively define property arrangements that set the degree of rivalry and excludability in a frequency pool without relying on international coordination between public actors to set these rules.

Therefore, this thesis finds it useful to explore the relationship between industrial actors as direct resource users and the property arrangements established in radio frequency pools at transnational level. This approach does not sideline the role of public actors in administering the radio resource at national or international level. Instead, it recognises that actors can organise differently at national and international level, leading to variations in the bundle of property rights established to harvest the common resource. This makes the radio spectrum a good example to test the role of industrial actors in defining property arrangements in transnational common pool goods. Against this background, the next chapter outlines the analytical framework used in the thesis to test the relationship between the dynamics of contestation and collaboration among private industrial actors drawing economic benefit from the use of the radio resource and the property arrangements that emerge in this transnational resource.

Chapter 2. Collective Action in Shared Resources: The Analytical Framework

This thesis starts from the assumption that private parties who extract economic value from a common pool good can sometimes organise to define complex yet stable property systems, regardless of the presence or absence of an external public authority with responsibility to regulate the common pool. The early regulation of radio frequencies reveals the role of industrial actors in defining operational and collective choice rules in the radio resource across borders. It identifies that industrial actors can organise to define alternative rule systems to those proposed by public actors. Lastly, it identifies that these alternative rule systems can be monitored and enforced in private transnational regimes for specific bands[35] or in public international regimes for the whole radio resource[36]. The thesis tests whether this evidence is replicated in the management of radio spectrum across time, focusing on the relationship between the organisation of private resource users and the structure of property arrangements in the transnational radio resource. Therefore, the thesis asks the following research question:

What determines the specific configuration of rights of access and use (operational property rights) and rights of management and exclusion (collective choice property rights) in a transnational common pool resource such as the radio spectrum?

The chapter presents the analytical framework used to answer this research question. The thesis adopts a variant of the Institutional Analysis and Development (IAD) framework put forward by scholars of public choice institutionalism (Aligica and Boettke 2011, Blomquist and deLeon 2011, McGinnis 2011, Ostrom 2011). The IAD framework has been widely used in the analysis of institutional arrangements for a

[35] For instance, the Commercial Radio International Committee operated as an industry association of the 'Big Four' for the private transnational regulation of the longwave broadcasting band. However, elements of this regime were also transposed into the international regulation of the radio resource, such as the allocation of international frequencies to communication services rather than to states. This example, outlined in *Chapter 1* of this thesis, reveals why private actors sometimes benefit from formalising aspects of private transnational governance into public international law.

[36] Scott, Cafaggi and Senden (2011) explain the difference between a transnational and an international regime as "not being constituted through the cooperation of states as reflected in treaties (the latter being the principal territory of international law). They are non-state (or private […]) in the sense that key actors in such regimes include both civil society or non-governmental organisations (NGOs) and firms (both individually and in associations)" (Scott, Cafaggi and Senden 2011: 3).

variety of policy questions including the governance of common pool goods (Ostrom 2011). The IAD framework benefits the analysis of property arrangements in the radio resource because it recognises that the physical properties of the resource, the attributes of the resource user group and the rules in existence are significant explanatory variables that shape the strategies of individuals in situations of collective action (Blomquist and deLeon 2011, Ostrom 2011). Therefore, the framework helps distinguish three variables on which the thesis focuses in order to answer the research question of who defines complex property arrangements in transnational commons. The first variable concerns the extent to which a private association of industry actors precedes or succeeds the decision of public actors to (re)-set rules of rivalry and excludability in the radio resource. The second variable concerns the distribution of private actor interests for a particular configuration of rivalry and excludability, as an attribute that shapes individual strategies inside the private association of resource users. The third variable concerns the distribution of private actor resources, particularly of intellectual property used in the technology that harvests the radio resource, as an additional attribute that shapes individual strategies inside the private association of resource users.

These three variables refer to the position of private actors in the organisation of collective action as well as to the attributes of private actors as a group that can determine a particular set of property arrangements to govern the common pool. Interestingly, these group attributes – i.e. diversity of actor interests and diversity of actor resources – are found to have different impact on achieving collective action in local and global situations of interdependence (Keohane and Ostrom 1995: 9). Several studies found that actor heterogeneity inhibits collective action in local common pool resources but facilitates it in the international arena (Holzinger 2008, Keohane and Ostrom 1995, Martin 1995, Libecap 1995). These findings make the study of property arrangements in the radio resource even more relevant, contributing to our understanding of the necessary attributes of private actors in organising stable and sustainable collective action at transnational level. These findings also inform the selection of case studies, which address the transnational regulation of five frequency bands in the European radio region across time. By tracing the formation of actor strategies in a given institutional setting, as well as the process of negotiating the degree of rivalry and excludability among private actors using the resource for the production of communications goods and services, the thesis can infer on the determinants of operational and collective choice property arrangements in transnational common pools. The following sections describe the main components of the research design applied in the thesis: the parameters of the analytical framework, the selection of cases and the methods used to analyse cases in order to answer the research question.

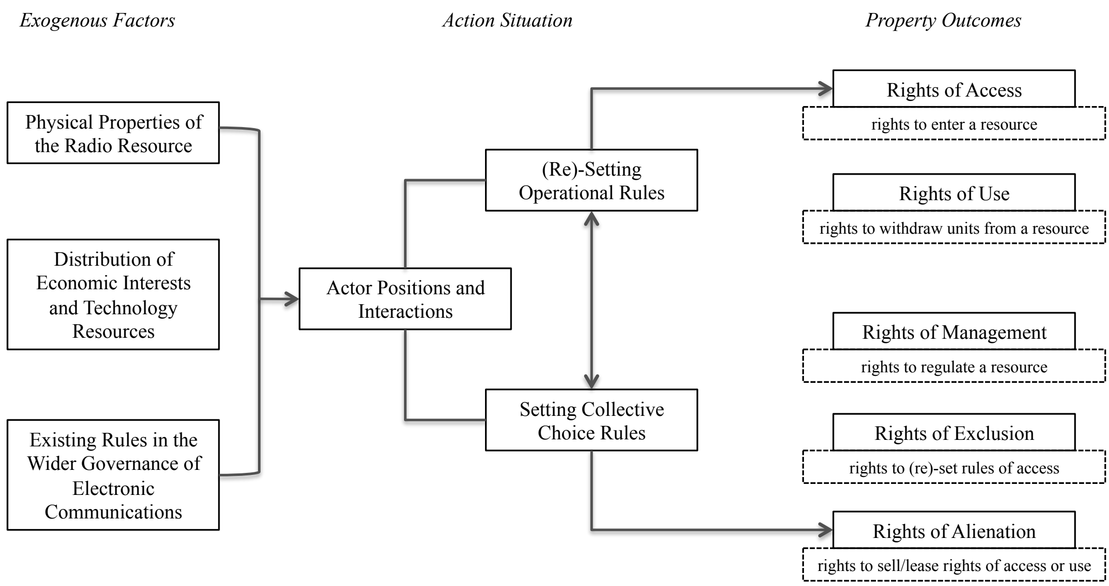
2.1 Parameters of the Analytical Framework

Previous analyses of situations of interdependence in common pool resources revealed that "many factors affect the strategic structure of a particular appropriation and provision problem, including the physical structure of a particular CPR [common pool resource], the technology available to the appropriators, the economic environment, and the sets of rules that affect the incentives that appropriators face" (Ostrom 1990: 50). Scholars of public choice institutionalism have identified and classified these exogenous variables that are present in most situations of interdependence (Ostrom 2011: 9) and that affect the incentives to cooperate towards the provision of these institutional arrangements (Keohane and Ostrom 1995: 15). These variables are: a) the physical properties of the resource; b) the attributes of the resource user group and c) the existing institutional arrangements that govern operational and collective choice behaviour at a given time (Ostrom 2011: 10). These variables constitute the main structural elements that shape actors' positions and interactions in an "action situation"[37] where operational and collective choice rules are negotiated in order to form property arrangements for the administration of common goods (*Figure 2.1*). This framework is known as the Institutional Analysis and Development (IAD) framework and, although it has been used in the analysis of social-ecological systems, it can have wider applicability in the analysis of complex social orders (Aligica and Boettke 2011, Blomquist and deLeon 2011, Ostrom 2011). Thus, the framework is a heuristic for situations of interdependence, structured upon groups of exogenous variables, which define the behavioural boundaries of an action situation (*Figure 2.1*). By recognising the complexity of exogenous variables that shape positive or negative incentives to

[37] The action situation is a simplified concept that describes "the social space where individuals interact, exchange goods and services, solve problems, dominate one another or fight", a type of decision-making arena where actors negotiate rule systems (Ostrom 2011: 11).

cooperate, the framework moves the analysis beyond short-term rationality in actor preferences.

Figure 2.1 Variant of the IAD Framework for Analysis of Property Arrangements in the Radio Spectrum as a Transnational Common Pool Resource



Source: Adapted from E. Ostrom (2011: 10)

Figure 2.1 describes the steps that will be followed in testing the relationship between the organisation of private resource users – i.e. industry actors – and the configuration of property arrangements in the transnational radio resource – i.e. operational rules and collective choice rules. Each case study starts with an investigation of the exogenous factors that could influence actor strategies for a particular configuration of rivalry and excludability in a shared resource. The variables considered for this analysis are: a) the presence of the public actor vis-à-vis industry actors in the wider governance of electronic communications, in order to assess whether industry action responds to a policy position of the public actor; b) the economic interests of industry actors for an outcome in the market for wireless communications, in order to assess whether homogeneity or heterogeneity of preferences results in different configurations of excludability in a radio frequency pool; and c) the technology capabilities held by industry actors, in order to assess whether the homogenous or heterogeneous distribution of technology resource among private actors results in different configurations of rivalry in a radio frequency pool (Keohane and Ostrom 1995, Libecap 1995, Martin 1995, Poteete and Ostrom 2004). The following sections discuss the main lines of debate around the distribution of economic interests and technology capabilities among resource users of local and transnational common goods. The following sections show how expectations derived from these main lines of debate have informed the operationalisation of variables and the selection of cases used in this thesis in order to test the relationship between the organisation of resource users and the configuration of operational and collective choice rules in transnational common pools such as the radio spectrum.

2.1.1 The Role of Public and Private Actors

The first factor to be analysed concerns the position of the public actor in the wider governance of electronic communications. *The question is whether the public actor – regulatory agency or government(s) – represents the principal authority that sets the configuration of property arrangements in a radio pool.* National and international law recognise the role of public authorities to regulate radio frequencies on their territory. However, as identified in *Chapter 1*, too close a focus on national spectrum policy runs the risk of diverting attention from complex negotiations concerning the level of rivalry and excludability in transnational frequency bands regulated by communications service rather than by sovereign state.

This question does not contest the analysis of spectrum policy as either inhibiting or enabling efficient resource use through a combination of exclusive licensing, licensing with secondary markets or conditioned open access (revisit *Section 1.2.4*). Instead, it questions that public regulation is the only instrument to ensure the stability of property arrangements in the radio resource, either by exclusive rights of use secured through licenses or by non-exclusive rights of use secured through conditioned access. Regardless of the specific configuration of property arrangements, the administrative presence of a public authority to create, monitor and enforce these rules is regarded as paramount in spectrum policy analysis.

The role of a single public authority to define, monitor and enforce property arrangements is, however, difficult to identify in the administration of transnational common pool resources, such as the radio spectrum. An easily observable reason is the absence of hierarchical authority to define, monitor and enforce property arrangements at the global level (Keohane and Ostrom 1995: 2). A less easily observable reason is the absence of a single node of authority and a single level of decision-making for the provision of a public good (Heritier 2002, Holzinger 2008). Considering the presence of polycentric systems of authority in the regulation of the climate, E. Ostrom (2010) noted that "the initial relevance of the polycentric approach is the parallel between the earlier theoretical presumption that only the largest scale was relevant for the provision and production of public goods […], and the contemporary presumption that only one scale is relevant for policies related to global public goods" (Ostrom 2010: 34). It is, thus, equally important to identify whether polycentric systems of authority are present in the regulation of the radio spectrum, since radio waves are inherently transnational and since the public good derived from them – i.e. wireless communications – is inherently mobile across national borders. In this context, too close a focus on a single public actor, or on negotiations among public actors at the international level, runs the risk of omitting important dynamics among private actors with different incentives to derive economic value from the common resource and with different strategies for setting rules of rivalry and excludability in the radio resource.

In this context, it is essential to identify the position of public actors vis-à-vis private actors in the wider governance of the radio spectrum at international level. Previous research has demonstrated the importance of "the threat of national or international regulation to the decision by corporate leaders to choose a self-regulatory strategy" (Haufler 2001: 106). Consequently, this analysis identifies whether private actors organise to define property arrangements in transnational commons as a result of the (re)-distributive positions of public actors (Haufler 2001) or as a result of their collective self-interest[38] (Streeck and Schmitter 1985). Lastly, this analysis identifies the configuration of authority between public and private actors at different levels of rule-making, monitoring and enforcement in the governance of transnational common pool resource (Black 2008, Cafaggi 2012a, Verbruggen 2013). Once it is identified whether the organisation of private actors precedes or succeeds the initial position of public actors to establish property arrangements in a radio frequency, the analysis can focus on the distribution of interests and capabilities among private actors as a form of mapping their rule preference for the degree of rivalry and excludability in the radio resource.

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[38] Research on transnational private regulation has already identified "Ostrom's paradox" when dealing with problems of collective action as a result of pollution or overcrowding of common resources, as these problems can be "effectively addressed through action by the very same market actors whose conduct caused the problem, but now acting collectively rather than individually" (Scott, Cafaggi and Senden 2011: 7).

2.1.2 The Diversity of Private Actor Interests

The second factor to be analysed concerns the interest distribution of private industry actors for a preferred configuration of excludability in a frequency band, as an attribute that shapes individual strategies for the type of property arrangements to be deployed in the radio resource. *The question is whether heterogeneity of economic interests for a particular distributive outcome of rivalry and excludability is more likely to result in minimal coordination over the institutional arrangement in a transnational resource pool.* Heterogeneity of interests has been identified as having different impact on coordination outcomes in situations of interdependence at local and international level (Abbott and Snidal 2001, Keohane and Ostrom 1995, Poteete and Ostrom 2004). On the one hand, studies of local common goods reveal that asymmetric interests can reduce the opportunity private individuals have to design stable and sustainable institutional arrangements to utilise the common pool (Martin 1995: 73, Ostrom 1995). On the other hand, studies of international public goods reveal that asymmetric interests can create opportunities for the formation of interest associations and, as a result, for mobilisation towards the design of stable and sustainable institutional arrangements (Abbott and Snidal 2001, Buthe 2009, Martin 1995, Werle 1998).

The definition of "interests" might explain variation in coordination outcomes at local and global level. Specifically, interest heterogeneity can refer to "evaluations of the individual benefits and costs of polices" (i.e. preferences over policies) and evaluations "of the outcomes themselves" (i.e. preferences over outcomes) (Keohane and Ostrom 1995: 7). Accordingly, this thesis defines private interests as the distribution of economic interests for a particular outcome of rivalry and excludability in the radio resource. This definition is informed by considerations that economic interests in wireless communications markets, which develop from the utilisation of the radio resource, play a major role in the formation of rule preferences over the degree of rivalry and excludability in the resource.

In this context, a group of private actors with diverse economic interests in communications markets might choose to cooperate in the design of operational rules in a given frequency band in order to reduce uncertainty over (re-)distributive measures put forward by a public actor or, in its absence, to reduce uncertainty over discovery and transaction costs in the market (Haufler 2001, Schmitter and Streeck 1999). Subsequently, complementary rather than fully aligned economic interests can achieve collective provision of property arrangements in a particular common pool, regardless of whether the group is formed of concentrated symmetric interests or not (Olson 1965). As Schmitter and Streeck (1999) noted, "highly interdependent sets of firms may develop a common interest in some kind of self-organized (associational) adjudication of internal conflicts over terms of exchange; this interest may be more likely to give rise to associative action than other common interests" (Schmitter and Streeck 1999: 27). As interdependence of action is high in common pools, the central question would not concern the impact of interest heterogeneity on cooperation per se, but the impact of interest heterogeneity on "the amount and type of cooperation […] leading to outcomes" (Keohane and Ostrom 1995: 16). The amount and type of cooperation is given by the complexity of a property arrangement in a common pool. Because the costs of defining collective choice arrangements (i.e. rights of management and exclusion) increase as the diversity of economic interests within the pool increases, then private actors are expected to prefer less complex operational arrangements (i.e. rights of access) based on exclusive individual property in order to secure their position of rivalry. Not only does individual property provide certainty over the degree of excludability in the pool, it also provides greater reliance on external actors to monitor and enforce arrangements based on existing forms of individual private property. Thus, operational arrangements based on exclusive individual property allow for a reduction in the costs of collective choice arrangements for re-negotiating the degree of excludability within the pool. Once the heterogeneity of economic interests in a particular pool is identified, the analysis can focus on the heterogeneity of capabilities held by individual private actors as a form of mapping their rule preferences over the degree of rivalry or competition inside the pool.

2.1.3 The Diversity of Private Actor Capabilities

The third factor to be analysed concerns the resource distribution of private industry actors for a preferred configuration of rivalry in a frequency band, as an attribute that shapes individual strategies for the type of property arrangements to be deployed in the radio resource. *The question is whether heterogeneity of resources for a particular distributive outcome of rivalry and excludability in a transnational resource pool is more likely to result in institutional arrangements based on exclusive individual property as opposed to exclusive common property.* The difference between individual private property and common private property rests in the willingness of private actors to invest in collective choice arrangements that privatise the rights to a pool without parcelling it into exclusive individual pieces[39] (revisit *Section 1.2.3*, McKean 2000). Then, the distribution of individual capabilities among private actors is an essential determinant of the level of rivalry in the allocation of the resource and, subsequently, of the type of cooperation chosen to establish internal operational rules (i.e. rights of use) in the common pool. As outlined in *Chapter 1*, the most important capability for radio resource users is intellectual property in the technology used to harvest the radio resource in order to produce wireless communications and to develop wireless communications markets. As E. Ostrom (1998) showed, technology extracts value and establishes and sustains property rights in a common pool (in Buck 1998: xiii). Without it, the radio resource would not be harvested at all.

A considerable number of studies has recognised the role of intellectual property[40] as an essential capability in negotiating governance systems for electronic communications markets at transnational level (Bekkers et al 2014, Bekkers and Liotard 1999, Schmidt and Werle 1998, Werle 2001). These studies address the relationship between patents and voluntary standardisation of technology solutions in electronic communications. Because most of these standards are open compatibility or interoperability interfaces between proprietary components, they hold an inherent tension between "the private character of IPRs [intellectual property rights] and the public interest that a standard wants to foster" (Bekkers, Verspagen and Smith 2002: 1142). As Maskus and Merrill (2013) explain "incorporating patented or patent-pending technologies in standards is virtually inevitable and generally beneficial, but there is a tension between owners and users of a patented technology" (Maskus and Merrill 2013: 1). However, most of the studies that explore the relationship between intellectual property capabilities and the strategies of private actors in the process of standardisation of wireless communications

[39] A brief definition of common property regimes is provided by Dagan and Heller (2001): "common property designated resources that are owned or controlled by a finite number of people who manage the resource together and exclude others" (2001: 557). Or, as an adaptation of Rose's definition, common property regimes designate common property on the inside and private property on the outside (Rose qtd in Dagan and Heller 2001: 557). Note that Rose's initial definition was "commons on the inside, property on the outside", which might be confusing as commons are a type of property.

[40] This thesis makes a clear difference between intellectual property as a capability of individual private actors and operational and collective choice arrangements as property institutions for governing common pool resources.

have linked these strategies to the development of property arrangements in electronic communications markets rather than property arrangements in the radio resource that allow these markets to form in the first place (Abbot and Snidal 2001, Krasner 1991, Schmidt and Werle 1998).

Because technology is the only means to harvest the radio resource for the production of wireless communications, distributional conflicts in the arrangements of wireless communications markets[41] should be mirrored, at least in part, by distributional conflicts in the arrangement of the wireless resource. Similar to asymmetries of interests, asymmetries of capabilities among private actors have led to different outcomes in local common goods and global public goods (Keohane and Ostrom 1995). The choice of a distributional equilibrium[42], which sets individual rents among private actors using the common resource, depends on the individual actor's ability to hold capabilities that translate into influence over property outcomes (Abbott and Snidal 2001: 362, Martin 1995: 79, Libecap 1995: 165). In the radio spectrum, holders of essential technologies that harvest the resource are likely to use this capability as influence in the negotiation of internal operational rules (i.e. rights of use) in favour of their technology capabilities. However, in local commons, heterogeneity of capabilities among private actors is less likely to lead to changes in property arrangements due to undesired changes in the allocation of the resource under the status quo (Libecap 1995: 165). In the provision of public goods at international level, heterogeneity of capabilities can lead to changes in property arrangements as long as some parties are willing to cover the cost of collective choice arrangements (i.e. management, exclusion, alienation) and as long as operational arrangements (i.e. allocation of use) reflect their technology capabilities (Abbott and Snidal 2001: 349, Martin 1995: 75). Nevertheless, both scenarios would indicate a preference for individual private property rather than common private property in order to reduce the costs of negotiating operational arrangements of resource allocation in the pool as well as in order to ensure certainty of resource rents based on the preferred technology capability. Under this circumstance, it

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[41] Abbott and Snidal showed that the process of technology standard setting is rarely neutral (2001: 351). Krasner confirmed this finding, showing that cooperation in transnational telecommunications markets are "characterized not by Nash equlibria that are Pareto suboptimal but rather by disagreements over which point along the Pareto frontier should be chosen, that is, by distributional conflicts rather than by market failure" (Krasner 1991).

[42] Out of an infinite number of distributional equilibria in situations of cooperation.

is important to analyse whether private actors with asymmetric capabilities choose other types of property arrangements than individual private property to allocate use of the radio resource.

The four case studies selected in this thesis will follow closely the analysis of these three variables: a) the presence of the public actor as a (re)-distributive authority of rivalry and excludability in a given frequency band; b) the diversity of economic interests among private actors as influencing a particular configuration of rivalry and excludability in a given frequency band, and c) the diversity of technology capabilities among private actors as influencing a particular configuration of rivalry and excludability in a given frequency band. As Keohane and Ostrom (1995) noted, heterogeneity in actor preferences and capabilities are treated as exogenous variables because "they are determined exogenously to the institutions designed to deal with specific collective action problems" (Keohane and Ostrom 1995: 10). Thus, economic preferences and technology capabilities inform the strategies of private actors in negotiating the distribution of operational (i.e. rights of use and access) and of collective choice arrangements (i.e. rights of management and exclusion) in a common pool. The following section provides the main criteria for the selection of cases that tests the relationship between the attributes of industry actors and the property arrangements selected for the governance of the radio resource as a transnational pool.

2.2 Case Selection

In order to test the relationship between the organisation of industry actors and the property arrangements that make up the governance of the radio spectrum, this thesis has selected four case studies that address the regulation of radio frequencies for wireless electronic communications in Europe, Radio Region 1 of the ITU:

- The regulation of the 900 MHz band for second generation cellular digital mobile communications in the late 1980s (Case Study I)
- The regulation of the 1.9 GHz and 2.1 GHz bands for third generation cellular digital mobile communications in the 1990s (Case Study II)
- The regulation of the 800 MHz band for mobile broadband in the late 2000s (Case Study III)

- The regulation of the 2.4 GHz and 5 GHz bands for wireless local area networks in the early 2000s (Case Study IV).

There are three broad considerations for the selection of these case studies. First, the thesis has selected a single natural resource – i.e. the radio spectrum – in order to explore changes in property rules in different frequency bands across time. Although frequency bands have different propagation characteristics, their main physical properties are largely the same across the commercial radio spectrum, allowing for good comparison across frequency pools and across time. The time element is particularly important, because it reflects different stages in the liberalisation of electronic communications and, as a result, different structural conditions for industry actors. Second, the thesis has selected commercial frequencies used to deploy a variety of electronic communications services such as mobile telecommunications, broadcasting and information technologies, allowing for comparison across industry sectors. Third, the thesis has selected a single geographic dimension of the radio spectrum, focusing exclusively on the regulation of radio frequencies in Europe, Radio Region I. As identified in *Chapter 1*, this geographic area is predisposed to problems of coordination and distribution due to the considerable number of industry actors operating in a high number of jurisdictions with developed electronic communications markets. In addition, this geographic area hosts the presence of a public transnational actor – in the form of the Commission of the European Union. Although radio frequencies in the region are regulated for a wider geographic area than the European Union, the presence of the European Commission is relevant in order to test the impact that a public actor might have on the organisation of private interests for the creation of property arrangements in a given band. Additionally, the presence of the European Commission can reveal more information about situations when industry actors rely on a public actor for monitoring and enforcing rule systems defined by private regimes.

A map of the case studies is presented below, in relation with the selection criteria on the independent variable[43]: a) the variation in the presence of a public actor with authority to (re-)distribute rivalry and excludability in a given frequency band, and b)

[43] As Burnham et al noted, this selection criteria follows the recognised practice in small-n research, by which "cases are typically not randomly selected – and in fact doing so might not be at all appropriate – but are selected precisely because they belong to a particular classification category on the independent variable" (Burnham et al 2008).

the variation in economic interests and technology capabilities among private actors negotiating operational and collective choice rules in a given frequency band.

2.2.1 The Presence of a Public Actor

The first consideration for the case selection is the presence of a public actor in a position to (re-)distribute rivalry and excludability in a given frequency band at transnational level. Having variability in the position of a public actor is important in order to test whether industry actors organise in response to the position of the public actor or in response to other considerations of collective self-interest. *Table 2.1* gives the variability in the presence and preference of the public actor – in the form of the Commission of the European Union – for a particular configuration of rivalry and excludability in the radio resource across the four case studies. Whereas "presence" refers to the existence of a European Commission with formal competences in electronic communications policy, "preference" refers to the explicit identification of a technology or service to be deployed in a given frequency band.

Table 2.1 Selection of Cases - The Presence of the Public Actor

	No Early Preference of Public Actor		**Early Preference of Public Actor**
No Presence of Public Actor	900MHz Band (Case Study I)	2.4GHz Band (Case Study IV)	—
Presence of Public Actor	800MHz Band (Case Study III)	5MHz Band (Case Study IV)	1.9GHz-2.1GHz Band (Case Study II)

Table 2.1 reveals that there is considerable variation in the presence and preference of the public actor across the four case studies selected in this thesis. *Case Study I* and *Case Study IV* (concerning the 2.4 GHz band) exhibit no presence and, subsequently, no preference of the public actor for a configuration of rivalry and excludability in the radio spectrum. This indicates that industrial actors responded to their private interests to organise in order to define property arrangements in the given frequency bands. At the opposing pole, *Case Study II* exhibits the presence of a public actor with a declared preference for a particular technology and/or service that could impact rivalry and excludability in the frequency band. In this case, it is important to examine whether industrial actors aligned their preferences to those of the public actor or if they put

forward alternative arrangements that represented their economic interests and capabilities more closely.

Table 2.1 shows how the four case studies fit within these two categories, representing the presence and preference of a political actor. On the issue of preference of a political actor, it is important to note that this refers, exclusively, to a technology or service preference. As explained above, the choice of technology used to withdraw value from a particular common pool resource is extremely important in guiding the degree of rivalry within a pool. If a political actor, as in *Case Study II*, expresses a preference for a given technology or service, this is expected to have a different impact on the organisation of private interests willing to derive economic value from a given band. Similarly, if a political actor does not express a preference but has a presence in early rule-making, as in *Case Study III* and *Case Study IV* (concerning the 5 GHz band), it is important to qualify whether private actors use the policy venues available with the public actor or whether they prefer to establish private venues for interest intermediation.

2.2.2 The Diversity of Interests and Capabilities of Private Actors

The second consideration for the case selection is the distribution of economic interests and technology capabilities among industry actors harvesting the radio resource for the delivery of mobile electronic communications. The distribution of these factors informs the strategies adopted by private actors in the negotiation of operational and collective choice rules as well as in the negotiation of the complexity of these rules.

Table 2.2 Selection of Cases - Diversity of Interests and Capabilities Among Private Actors

	Low Diversity of Capabilities	**High Diversity of Capabilities**	
Low Diversity of Interests	900MHz Band (Case Study I)	1.9GHz-2.1GHz Band (Case Study II)	
High Diversity of Interests	2.4GHz Band (Case Study IV)	800MHz Band (Case Study III)	5GHz Band (Case Study IV)

Table 2.2 shows how the four case studies fit within these two categories, representing the diversity of interests and capabilities among industry actors as they enter into negotiations about the level of rivalry and excludability in a given frequency band.

Based on the theoretical expectations outlined in *Section 2.1*, *Case Study I* exhibits homogeneity of both interests and capabilities among private actors. This symmetry is expected to encourage self-organisation in the transnational resource, but to prevent the development of common property arrangements based on complex collective choice rules. *Case Study II* exhibits homogeneity of interests combined with heterogeneity of capabilities among industry actors. This situation is also expected to encourage self-organisation in the transnational common, but to favour individual property arrangements that reflect the capabilities of actors with dominant technologies. Case *Study III* and *Case Study IV* (concerning the 5 GHz band) exhibit heterogeneity of both interests and capabilities among industry actors. These asymmetries are expected to discourage self-organisation in the transnational resource, because industry actors are less likely to be willing to invest in costly collective choice arrangements. In this situation, industry actors are expected to rely on individual property arrangements supplied by the market and enforced by external public actors.

The validity of these expectations will be tested in the four case studies addressing the regulation of four frequency bands. The next section presents the methods used to test these assumptions about the relationship between the organisation of private actors and the property arrangements developed in each frequency band.

2.3 Methods

This thesis is structured as a theory testing exercise that follows the causal process by which an association of private actors can shape property arrangements in a transnational common pool such as the radio spectrum. In order to follow this causal process, the thesis relies on two complementary methods of analysis. The predominant method is process tracing in small-n comparative cases, which is used in order to identify the process of negotiating operational and collective choice rules in different frequency pools. The systematic use of process tracing across the different case studies is reinforced by the use of network analysis of technology exchanges among industry actors in communications technologies, in order to provide a visualisation of the relationship between industry users of the radio resource across time.

2.3.1 Process Tracing

There is a growing recognition in the literature that systematic process tracing of small-n cases has considerable value for developing theory-oriented explanations due to its attention to the most important elements in the causal mechanism generating a particular outcome or class of outcomes (Hall 2008: 304, 306). As a method, "process tracing rests upon the discovery of a chain of events, rather than a distribution of values of variables, that leads to certain outcomes" (Caporaso 2009: 70). Thus, the method of process tracing is best suited for the analysis put forward in this thesis, because it helps identify the causal relationship between the independent variable (i.e. public or private actors) and the dependent variable (i.e. property arrangements in the common pool). Specifically, the method of process tracing allows considerable scrutiny of the position of public actors, the configuration of interests and capabilities of private actors as well as their progressive interactions and negotiations, in order to identify the causal mechanisms between these configurations of interests and capabilities, and the property outcomes established in the radio resource.

Each case study relies on the systematic examination of the position of the public actor as well as the negotiation between private actors within interest associations that provide the organisational framework to negotiate technology systems requiring a particular configuration of operational rules (rules of access and rules of use) and collective choice rules (rules of management and rules of exclusion) for managing the transnational radio resource. This internal account is sustained by a close examination of primary and secondary sources, which record and analyse the negotiations that took place in industry associations during the development of each case study. Primary sources cover minutes of meetings and official reports of negotiations regarding the technical specifications of electronic communications systems to be deployed in the frequency bands investigated in each case study, most notably the European Conference of Postal and Telecommunications Administrations (CEPT)[44], the European

[44] CEPT Reports and ECC Decisions, Recommendations and Reports are publically available at http://www.erodocdb.dk. GSM Plenary Meeting Reports (1982-1991) and GSM-CEPT Documents (1982-1988) referenced in this thesis are available at www.gsm-history.org, permission to reproduce granted by Hillebrand & Partners. Rare GSM Documents (i.e. Digital Cellular Cooperation Agreement and Annexes on IPR Policy (1985), Quadripartite Agreement (1986), GSM MoU (1987)) are available at www.gsmhistory.com, permission to reproduce granted by Stephen Temple. A selection of these primary sources is also archived in the CD ROM attached to F. Hillebrand

Telecommunications Standards Institute (ETSI)[45], the Institute of Electrical and Electronics Engineers (IEEE)[46], the International Telecommunications Union (ITU)[47], the 3G Partnership Project (3GPP)[48], the Next Generation Mobile Networks Alliance (NGMN)[49] and the Wi-Fi Alliance[50]. Secondary sources cover personal accounts of radio spectrum policy experts and industry experts[51] who were present at the meetings. Secondary sources also include specialist reports and news reports[52] about the main events. In order to limit bias in the account of these events, triangulation of these three types of sources is used in each of the cases analysed in this thesis.

The method of process tracing is applied in a systematic manner across the four case studies through the consistent operationalisation of the key independent and dependant variables identified in the IAD framework adopted in this thesis (*Figure 2.1*). Thus, each case study applies the method of process tracing to the same observables using operational definitions that have been employed in the specialist literature analysing

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(2002) *GSM and UMTS: The Creation of Global Mobile Communication*, John Wiley & Sons, copyright clearance granted by John Wiley and Sons.

45 ETSI SMG Plenary Meeting Reports (1992-1999) and Selected ETSI SMG Documents (1993-1999) are archived in CD ROM attached to F. Hillebrand (2002) *GSM and UMTS: The Creation of Global Mobile Communication*, John Wiley & Sons, copyright clearance granted by John Wiley and Sons. The complete set of specifications, reports and documents for GSM and SMG are archived by ETSI at www.etsi.org (members access).

46 IEEE 802.11 Documents (2000-2015) of the IEEE Standards Association are publically available at https://mentor.ieee.org/802.11/documents.

47 The complete list of ITU Conferences, Assemblies and Events is publically available at the History of ITU Portal, http://www.itu.int. Permission to reproduce ITU Conference Documents and ITU-R Recommendations referenced in this thesis has been granted by the Legal Affairs Unit of the ITU.

48 Selected 3GPP Documents referenced in this thesis are archived in CD ROM attached to F. Hillebrand (2002) *GSM and UMTS: The Creation of Global Mobile Communication*, John Wiley & Sons, copyright clearance granted by John Wiley and Sons.

49 Selected NGMN White Papers referenced in this thesis are publically available at www.ngmn.org/uploads/media.

50 Selected Wi-Fi Alliance Press Releases referenced in this thesis are publically available at http://www.wi-fi.org/news-events/press-releases.

51 Personal accounts of key policy and industry experts present at negotiations in GSM and SMG are available at www.gsm-history.org, www.gsmhistory.com, as well as in the collection by F. Hillebrand (2002) *GSM and UMTS: The Creation of Global Mobile Communication*, John Wiley & Sons.

52 Selected from media articles collected from Business Wire, Electronic Engineering Times and The Financial Times as well as from IEEE Journals and Proceedings of the IEEE.

management regimes in common pool resources and extending their application to the field of wireless communications (Bromley et al 1992, Libecap 1995, Martin 1995, Ostrom 1990). Based on the discussion in the previous sections, a summary of observables that will be consistently analysed across the four case studies, together with their operational definition, is introduced in *Table 2.3*.

Table 2.3 List of Observables (Independent and Dependant Variables) with their Operational Definition

Variables	Concept	Operational Definition
Independent	*Initial Position of Public Actor*	European Commission as transnational public actor with: a) variable position of authority/ competence in defining, monitoring and enforcing property arrangements in radio spectrum (e.g. corporate actor) b) variable preference for communications systems or communications services (e.g. agenda setter)
	Initial Distribution of Economic Interests among Private Actor	Economic interests as actor preferences for a specific economic outcome of rivalry and excludability in a frequency pool (e,g. technology coexistence, technology exclusion, service sharing)
	Initial Distribution of Technology Capabilities among Private Actor	Technology capabilities as distribution of power or leverage in negotiations (e.g. dominance of a technology as mechanism for extracting value from a frequency pool)
Dependent	*Rules of Access*	Access as permission to enter a frequency pool based upon: -geography (e.g. CEPT) -technology specification (e.g. GSM, cdma2000) -service specification (e.g. broadcasting, mobile cellular telecommunications)
	Rules of Use	Use as rate of withdrawal of resource units from a frequency pool based upon: -type of use (e.g. technology or service) -relationship between users (e.g. compatible as systems coexistence, conflicting as systems interference)
	Rules of Management	Management as ability of negotiating actors to define conditions of participation in decision-making, to define conditions of monitoring and to define and change conditions of operation (access and use) in a frequency pool
	Rules of Exclusion	Exclusion as ability of negotiating actors to define and change rules of access

Source: Based on Bromley et al (1992) and Ostrom (1990)

2.3.2 Network Analysis

Although this thesis relies on process tracing in order to identify the strategies of actors involved in the negotiation of property arrangements, it uses network analysis of technology transfers in the electronic communications sector in order to provide additional evidence on the pattern of coordination among industry actors negotiating property arrangements. Based on graph theory, network analysis provides descriptive statistics on the position of influential actors in the electronic communications sector and the relationship between actors in clusters of influence. Because technology determines and sustains property on the radio resource (Ostrom in Buck 1998: xiii), network analysis is conducted to identify relations of strategic association based on technology transfers. In order to measure these relationships, this thesis uses network analysis of publically reported strategic alliances that took place from 1990 to 2010, covering the time span of three out of the four case studies[53] (*Case Study I* to *Case Study III*).

Alliance data is gathered using the *Thomson Reuters SDC Platinum Database*. The information on strategic alliances in this database has been previously used in empirical studies exploring the network structure created by publically reported alliances in the industry (Bekkers and Martinelli 2012, Sampson 2004, Schilling and Phelps 2007). Alliance data has been aggregated based on the membership of actors in two industry classification groups, as indicated by the primary Standard Industrial Classification (SIC): *Telephone and Telegraph Apparatus* (3661 SIC Primary) and *Radiotelephone Communications* (4812). In order to show changes in network structure across case studies, alliances are measured over five-year time frames, from 1990 to 2010[54].

Network analysis contributes to the main argument of the thesis in two ways. First, it offers a visualisation of the structure of the alliance network over a five-year period[55], as a proxy of the nature of associability among industry actors. Second, it calculates and

[53] Case Study IV concerns the information technology and computing industry. Strategic alliances in these sectors are not fully disaggregated in order to allow for reliable descriptive statistics of technology transfers between actors in these sectors.

[54] The life of strategic alliances is not reported in the SDC Platinum Database. The network analysis assumes that the typical duration of a strategic alliance varies from three to five years, which is in line with previous research (Schilling and Phelps 2007).

[55] All alliance types are included in the analysis. This includes joint ventures, research and testing collaborations and joint service deployments. However, it excludes all joint ventures that are reported as individual entities. Alliances where subsidiaries of parent companies were reported have been recoded to reflect the position of the parent company. This is because the transfer of knowledge in the form of R&D, testing or patents is easily diffused from parents to subsidiaries. See Schilling and Phelps (2007) for a similar approach. Alliances with more than two partners, which correspond to the dyadic coding for analysing networks, have been regrouped in dyadic form.

visualises network metrics that allow us to identify key firms, key clusters and their relationship in the transfer of knowledge within the network, as a proxy of the extent of associability among industry actors. It refers to firms as nodes and to relationships between firms as edges. This thesis uses three network metrics to analyse strategic relations in the industry. First, degree centrality shows how connected an individual entity is to other members in the network. It represents a count of the total number of edges that are connected to a node and is a measure that reflects a position of advantage in exchanges with other members. The graphs in this thesis visualise degree centrality by the size of the node and provide the exact measure in a detailed table. Second, eigenvector centrality measures the influence that a node has in the overall network. The graphs in this thesis visualise eigenvector centrality by variation in the shade of the nodes, from grey (small eigenvector centrality) to black (high eigenvector centrality). Lastly, the Newman clustering algorithm is applied to visualise groups of industry actors that form clusters of technology transfers in the wider network. The graphs in this thesis visualise clustering analysis by marking edges between nodes in different colours.

2.4 Conclusions

The following chapters will address negotiations about operational and collective choice rule systems that govern the radio frequency bands that make up the totality of case studies analysed in this thesis. Each case study will follow closely the Institutional Analysis and Development conceptual framework adopted in this thesis (*Figure 2.1*), which focuses on the relationship between a number of independent variables (i.e. the position of the public actor, most notably the European Commission; the configuration of economic interests and technology capabilities of private actors organised in formal and informal industry associations) and the dependent variables (i.e. the resulting operational and collective choice property arrangements in each of the designated frequency bands). The use of process tracing, combined with network analysis, offers the possibility to follow this causal relationship closely, in order to shed light on theoretical considerations about the role of public versus private actors in the rule making, monitoring and enforcement of regimes governing transnational common goods as well as on theoretical considerations about the configuration of actor attributes most likely to result in stable and comprehensive property systems in transnational common pools such as the radio spectrum.

Chapter 3. Regulating the 900 MHz Band: Devising Operational Rules in Regional Pools

This chapter traces the creation of property arrangements in the 900 MHz frequency band for the deployment of digital mobile cellular communication services, as initiated across Western Europe in the early 1980s. In this case, industry actors coordinated to define operational rules of access and operational rules of use in order to extract economic value from the 900 MHz band, in the absence of a transnational public actor with authority to manage telecommunications markets or the regional radio resource – i.e. the European Commission. In contrast, industry actors – particularly telecommunications operators (PTTs[56]) – had considerable authority in organising both telecommunications markets and the radio resource at the national level, but with limited coordination at the regional level. In this case, the initial distribution of interests and capabilities among industry actors reveals a situation of symmetric interests for extracting economic value from the 900 MHz band, with the aim to create new mobile communications markets, combined with a situation of relatively equal distribution of technology capabilities among the negotiating actors.

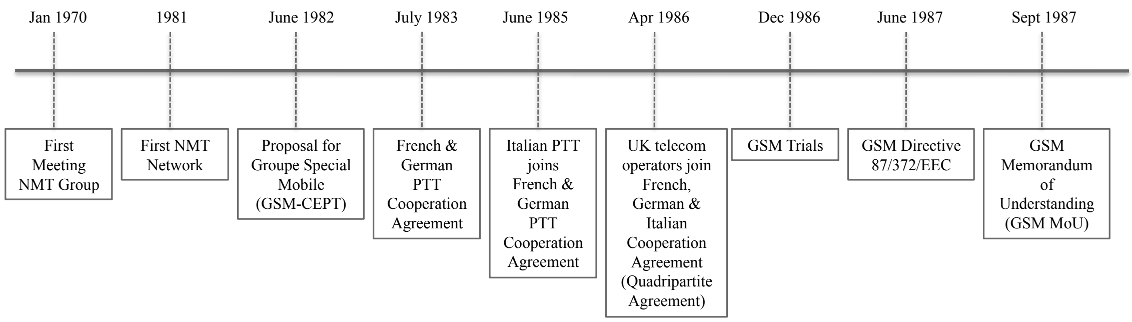
The case of the 900 MHz frequency band in the 1980s is, thus, useful in order to test the relationship between the organisation of industry actors and the configuration of property arrangements resulting from negotiations among these actors, in conditions of homogenous interests in the economic outcome derived from harvesting the band and homogenous distribution of capabilities in developing technology solutions to extract economic value from the band. Theoretical expectations based on the study of property arrangements in common pool resources would indicate that this situation of homogenous interests and homogenous capabilities is most likely to result in well defined collective choice rules of management and exclusion by a group of private users (Ostrom 1995). Moreover, this configuration of interests and capabilities is most likely

[56] Regarding the private character of these industry actors, it should be noted that, although some telecommunications operators were also public administrators (PTTs), their activity in devising the regulatory rules for the 900 MHz frequency band (in GSM-CEPT) focused on the definition of property arrangements for commercial purposes, i.e. the creation of a new market in mobile communications. Pelkmans (2001) adopted a similar approach, describing negotiations for the GSM standard as "actions of private governance by the European telecoms operators" (2001: 433).

to result in collective choice arrangements that sustain operational arrangements based on common rules of use and exclusive rules of access – i.e. common exclusive property.

Therefore, this chapter traces the negotiation process among industry actors involved in the regulation of the 900 MHz frequency band at transnational level, in order to investigate whether the theoretical expectations presented above are met. These negotiations lasted over a decade, so a timeline of main events is introduced to guide the reader through the development of this bargaining process (*Figure 3.1*). Over this timeline, the case study follows the analytical framework introduced in the previous chapter, which looks first at the position of the public actor and second at the distribution of interests and technology capabilities among private actors (*Section 3.1*), in order to then trace the bargaining process that results in a given configuration of operational and collective choice rules in the transnational radio resource at 900 MHz across Western Europe (*Section 3.2*).

Figure 3.1 Timeline of Main Events in the Regulation of the 900 MHz Band for GSM Mobile Communications Systems in the 1980s



The chapter finds that industry actors were able to establish private cooperation in order to extract economic value from the collective use of the 900 MHz band by developing a new mobile communication system for harvesting the resource called Global System for Mobile Communications (GSM). However, although industry actors were able to agree common rules of access and use of the radio resource based on favourable technology exchanges among members, which would lower their internal rivalry, they did not devise rules of management and rules of exclusion that would successfully control entry by new actors. Thus, the theoretical expectations put forward by studies of common pool resources are only partially met. The resulting industry association took the form of a Memorandum of Understanding (GSM MoU) with limited capacity to monitor commitments to internal rules of use and internal rules of access, which destabilised the initial levels of rivalry and excludability agreed collectively.

This case reveals a scenario whereby private actors agree operational rules of access and use in the absence of a public actor, but they do not devise collective choice rules of management and exclusion in order to strengthen the operational rules collectively agreed upon. This scenario results in limited mutual monitoring, which requires the intervention of the public actor to stabilise property arrangements initially agreed by industry actors. Due to limited mutual monitoring among industry actors, internal rivalry among members increased and the preferred property arrangements in the transnational frequency pool at 900 MHz, in Western Europe, relied on principles of individual exclusive property rather than on principles of common exclusive property.

3.1 The Formation of Actor Strategies in the Wider Governance of Telecommunications

This section traces the origins of strategies adopted by industrial actors, which informed their positions in the negotiation of rules for the collective use of the 900 MHz band. It looks at the formation of actor strategies – both public and private – in the wider context for governing telecommunications, in order to identify the origin of their interests and capabilities. In the late 1970s, in Western Europe, the first systems of wireless telecommunications – also known as analog cellular communications – were being deployed by Postal Telegraph and Telephone Agencies (PTTs) acting in their dual capacity as operators and public administrators. These analog networks had local or national coverage and were based on proprietary standards developed according to vertical relations between national operators and manufacturers. Coordination between these networks was minimal and, if necessary, was achieved in the European Conference of Postal and Telecommunications Administrations (CEPT) – a voluntary association of telecommunications operators. The Commission of the European Community (EC), of then nine members[57], had limited powers to harmonise telecommunications policy in the union. However, in 1982, PTTs in Western and

[57] The founding six – Belgium, France, Germany, Italy, Luxembourg and the Netherlands (1957) – followed by Denmark, Ireland and the United Kingdom (1973).

Northern Europe[58] agreed to jointly regulate the 900 MHz band in order to provide a cross-border public network for mobile communications. This turn of events can be explained by two factors. First, changes in the global market structure as a result of growing international trade in telematics and telecommunications, which questioned the inward looking, fragmented nature of telecommunications networks across Western Europe. Second, changes in the European market structure as a result of competitive pressures from PTTs in Denmark, Finland, Norway and Sweden, who collectively developed an international network for mobile communications in a single, harmonised frequency band.

3.1.1 The Structure of the System of Governance in Telecommunications

Mobile cellular communication systems across the world developed in an institutional setting characterised by minimal coordination among telecommunications systems interconnected at national borders (Genschel and Werle 1993). Although the radio spectrum continued to be allocated by communications service at international level – in the Radio Regulations of the International Telecommunications Union (ITU) – national spectrum policy continued to be inward looking, based on market dynamics within the territory of each ITU member (revisit *Section 1.2*). In Europe[59], the regional allocation of spectrum confirmed this practice of parcelling wavelengths to service operators with national coverage in conditions of service monopolies[60] (Wormbs 2011: 99). Across Europe, the first systems of wireless telecommunications – also known as analog cellular communications – were being provided by Postal Telegraph and Telephone Agencies (PTTs) acting in their dual capacity as operators and public administrators[61]. Often, the PTTs would procure these systems from national manufacturers, following vertically integrated relations of production whereby the PTT would control research,

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[58] Both members and non-members of the EC.

[59] As explained above, this thesis treats the boundaries of "Europe" as limited to member states of the European Conference of Postal and Telecommunications Administrations. See the List of Acronyms for details of individual member states in CEPT.

[60] Although Wormbs' (2011) study looks at the allocation of broadcasting services, the same principles applied to allocations of analogue services, as it will be discussed below.

[61] By comparison, in the United States, Bell Systems and subsequently AT&T were running a regulated private monopoly.

development and design, directly or indirectly (Genschel and Werle 1993: 206). However, even within national borders, these analog networks were limited in space and scope compared with contemporary mobile communications networks. Their capacity was limited to small areas of coverage and small numbers of customers, while bulky devices were generally mounted on transport systems such as busses or trains (Farley 2005). Therefore, at the time, cross-border coordination in wireless communications was minimal and concerned only established mechanisms for ensuring non-interference and overcrowding.

In Europe, the regional association concerned with coordination in wired and wireless communications was the European Conference of Postal and Telecommunications Administrations (CEPT). Established in 1959, the CEPT was a voluntary organisation whose membership comprised of representatives of national PTTs across the European continent. Decision-making within the CEPT was achieved through consensus and, as Reid noted, it mostly concerned policy issues regarding the interconnection of wired telecommunications networks[62] (Reid 1977: 308). Thus, distributional problems of collective action in wireless communications across borders did not make the agenda of the CEPT.

This mode of governance, characterised by Genschel and Werle (1993) as hierarchically structured with minimal coordination across borders[63], came under structural pressure in the 1980s. The strongest was the competitive pressure of the electronics and communications industries in the United States (*Table 3.1*). Following World War II, the US government made considerable investment in research and development (R&D) in these industries, which led to the development of the low cost transistor, the silicon microprocessor, the integrated electrical circuit as well as the cellular system of wireless communications[64] (Farley 2005). These developments were deemed revolutionary

[62] For instance, a frequent policy issue was setting international tariffs for telecommunications. In the age of monopolies, long-distance lines would subsidize local loops and, as a result, they were attractive business segments in the natural monopoly model.

[63] Genschel and Werle (1993) highlight that hierarchies rely on authority whereas regimes use regulations (1993: 207). The authors explain that minimal coordination occurred largely because technical specification for interconnection emerged ex post the adoption of incompatible national systems.

[64] The cellular system was invented by Bell Laboratories in the late 1960s and increased the attractiveness of investments in wireless telecommunications. Cellular systems operate by dividing a geographical area into multiple cells and placing a base station in

because they facilitated more reliable automated services in telecommunications and telematics (Dalum et al 1999).

In turn, these developments strengthened the position of the telematics and telecommunications industry of the US vis-à-vis its main competitors in Europe and South East Asia (*Table 3.1*). At the time, the OECD published several studies on the evolution of these industries in the global market, reporting a "technology gap" between the two sides of the Atlantic (OECD 1968, 1970). This position was confirmed by political leaders of the European Communities (EC), reporting that few European firms were large enough to compete with "technology giants" such as AT&T, Motorola or IBM, which were becoming increasingly visible in the European market (Davies and Brady 1998, EC 1980, EC 1983, Pollack 1994, Sullivan 1984, Woolcock 1984).

Table 3.1 Export Market Shares (%) in Electronic Communications, 1981 and 1991

	Electronics (%)		**Office Machinery & Computers (%)**	
	1981	**1991**	**1981**	**1991**
France	5.0	5.2	7.3	5.7
Germany	11.7	10.6	12.3	9.0
Italy	2.6	2.7	4.8	3.9
United Kingdom	5.5	5.6	8.6	9.9
Japan	41.0	37.8	11.0	24.7
United States	16.2	21.4	38.6	26.9

Source: OECD, Main Science and Technology Indicators

These market changes had also manifested in increased pressures for standardisation of products in the telecommunications and telematics industries. The European market was very attractive for US firms operating in this sector and, as a result, the United States pressed for an increase in global technology trade in the General Agreement on Tariffs and Trade (GATTs). Although the Tokyo Round (1973-1979) did not discuss the

each of the cells. The geographical area is also equipped with a central switch, able to process and send information about the user to the base stations. Cellular technology remains, to date, the basis of mobile telecommunications systems.

liberalisation of telecommunications markets[65], it established international codes for the elimination of technical barriers to trade and promoted international standardisation of technical systems in these sectors (Alabau and Guijarro 2011: 41).

However, an increase in the production of voluntary international standards in telecommunications had put pressures on decision-making within the ITU. At the time, the International Telegraph and Telephone Consultative Committee (CCITT) of the ITU was the main standardisation organisation in telecommunications. An increase in the number of participants, while maintaining the established practice of decision-making by consensus, was becoming costly for telecommunications companies participating in the CCITT. Besides, the voluntary nature of international standards increased the possibility of non-compliance while maintaining the high costs of collective development (Genschel and Werle 1993: 217).

In this context, the increased costs of standardisation at international level pointed at regional organisations as a more suitable level for coordination (Besen and Farrell 1991: 311, Reid 1977: 305). In Europe, the CEPT provided this institutional structure but had limited organisational capacity for tackling distributional issues of standardisation. As outlined above, the CEPT was largely an association for telecommunications policy coordination, rather than for technical standardisation (Reid 1977). Simultaneously, changes in the institutional structure of the EC were opening up alternative mechanisms for coordination in telecommunications markets. However, as the next section reveals, this decision-making venue was not sufficiently developed at the time, because PTTs were unwilling to cede control over telecommunications policy to the Commission of the European Communities and, as a result, preferred standardisation in the voluntary CEPT.

3.1.2 The Initial Position of the Public Actor

Within the EC, the effects of increased competition and liberalisation of international technology markets translated into an internal industrial crisis associated with the institutional weakness of the European project (Pollack 1994, Sullivan 1984). As early as 1972, the EEC Heads of State/Government recognised this relative weakness and

[65] Telecommunications services were first discussed in the Uruguay Round of GATT negotiations, which took place from 1986 to 1994.

proposed "a single industrial base for the Community as a whole" (EC 1972)[66]. By the early 1980s, the European Commission was also questioning the ability of individual Members to effectively compete on their own in international markets for telecommunications and telematics:

> "One example […] is the development of a new family of time division switches: their development cost varies between $700 million and $1,300 million according to the manufacturer. Knowing that to provide a reasonable return on development costs of $1,000 million, sales of $14,000 million are necessary, one wonders how such a return could be obtained on a telephone switch of this sort given that the British market is worth $7,200 million, the French market $10,900 million and the German market $11,700 million?" (EC 1983c)

In the early 1980s, at the start of the liberalisation process, the European Commission was itself trying to tip the balance of competences in its favour. Hence, between 1980 and 1985, the Commission's main objective was the liberalisation and harmonisation of telecommunications equipment markets, rather than the liberalisation of telecommunications services run by the PTTs. This is an important distinction that clarifies the position of the European Commission in the coordination of telecommunications markets. It shows that the Commission had limited powers of rule making in telecommunications policy in the EC.

Between 1980 and 1985, the Commission made several Recommendations in the field of telecommunications, focusing primarily on the equipment market. Following the *Declaration on the European Union* at the Stuttgart European Council (1983) it proposed the creation of a single market for telecommunications network components and terminals, in order to facilitate a single industrial policy as flagged by the European Council (EC 1983a, 1983b). The proposal was adopted by the Council of Ministers in 1984. However, the Commission also proposed the creation of a Telecommunications Body to be placed under its authority, in order to facilitate harmonisation of telecommunications policy (EC 1983b). This proposal, which would have removed authority over telecommunications services from the PTTs, was rejected by the Council of Ministers. Instead, the Council set up the Senior Officials Group in

[66] At the 1972 Paris Summit, the EEC Heads of State or Government outlined the objectives and the policies to be pursued with a view to achieving a European Union. At the Summit, the Heads of State or Government agreed that "*it is necessary to seek to establish a single industrial base for the Community as a whole*". For the full declaration, see EC (1972) *Statement from the Paris Summit*, Bulletin of the European Communities, Oct 1972, Vol 10, Luxembourg, pp. 14-26.

Telecommunications (SOG-T), which was exclusively formed of representatives of the PTTs and did not respond directly to the Commission.

This clarifies the position of the public actor vis-à-vis industrial actors in telecommunication policy in the EC at the time. First, the European Commission had limited authority in telecommunications policy in the early 1980s. Prior to the Single Act (1987), the PTTs were de jure excluded from the liberalisation of public procurement (Hulsink 1999: 75-108, Sauter 1995: 96). Second, the Commission did not question the jurisdiction of PTTs over telecommunications policy or over the delivery of telecommunications services. In fact, some authors have pointed out that, during this time, the Commission’s position responded to international pressures for liberalisation of the telecommunications equipment markets, as stipulated in the 1979 GATT Agreement, rather than to its internal agenda to acquire formal competences in the sector (Alabau and Guijarro 2011: 41). Third, and of most relevance, the PTTs had already established coordination mechanisms within the CEPT, following a logic of minimum harmonisation of telecommunications policy across a geographic area greater than the EC. This coordination mechanism was preferred by the PTTs because it concerned the wider geographic area of Europe, rather than exclusively the EC, and because it followed the preferred consensus decision-making to arrive at voluntary policies. As Pollack (1994) noted, the Commission had to effectively compete with an already established association where a preferred policy coordination mechanism was already in place (1994: 99).

In fact, in 1984, the Council clearly stated that telecommunications administrations should “consult each other, preferably in the framework of CEPT, before they introduce any new service, notably between Member States with a view to establishing common guidelines so that the necessary innovation takes place under conditions compatible with harmonization” (Art 1, EC 1984). Even the European Commission clearly specified that, in telecommunications services, the Community was “to support the telecommunications administrations in programmes of harmonisation established in CEPT and CCITT” (COM(80) 422 final). Thus, at the time, the EC was not a preferred decision venue for the PTTs. In contrast, the CEPT provided a decision framework that gave each PTT sufficient weight to influence the final outcome regarding the harmonisation of telecommunications policies. The next section clarifies the distribution of economic interests and technology capabilities that determined these industrial actors to enter negotiations for the deployment of wireless communications services in the CEPT.

3.1.3 The Initial Distribution of Private Interests and Private Capabilities

In the early 1980s, the European PTTs continued the established practice of building incompatible wireless telecommunications services for their respective markets. Although the PTTs agreed on minimum levels of cross-border and cross-frequency interference, they did not harmonise these networks. On the contrary, PTTs with the largest telecommunications markets adopted incompatible standards for their analog cellular networks. The majority of these networks were still organised following the vertical relationship between national operators and manufacturers. Hence, the German Bundespost (DBP) opted for the C-Netz standard developed by Siemens, the French Direction Générale des Télécommunications (DGT) opted for the Radiocom 2000 standard developed by Matra and Alcatel, the Italian Società Finanziaria Telefonica (STET) opted for the RTMI/RTMT standard, while British Telecom and Racal Electronics – the two licensed operators in the United Kingdom[67] – opted for the AMPS standard developed by AT&T and Motorola from the United States (Ibrahim 2006: 140).

This situation reveals the economic interests of industrial actors – both service operators and manufacturers – in wireless communications. In the early 1980s, analog networks were providing limited coverage with highly variable numbers of customers. Generally, these numbers varied form 1,000 customers to 30,000 customers, mostly businesses (*WCIS Database*). Depending on its scope, a network of approximately 30,000 customers would have essentially populated an entire frequency band using the analog

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[67] Similar to the divestiture of AT&T and Bell Systems in the United States, the United Kingdom adopted the Telecommunications Bill of 1981, which kick started the privatization process of British Telecommunications and the creation of a number of subsidiaries. In 1983, licenses for radio cellular networks were granted to Cellnet (BT and Securicor) and Racal Vodafone (Milicom, Comvik of Sweden and Hambros Hank). See, OFCOM (2013) *A Brief History of Recent UK Telecoms and Oftel*. However, the two licensees were required to develop a single radio interface for their respective networks, so that customers could interconnect and roam between the two. A common interface is important for automatic roaming, which lies at the core of cellular networks, allowing subscribers to automatically switch from the base station of a network when moving from cell to cell, even if they don’t belong to operator whose infrastructure it is.

technology of the time. However, analog networks across Western Europe rarely reached maximum capacity in the late 1970s and, as a result, most operators focused on network development within their territory. Even if networks reached full capacity, then more allocations would be made in adjacent radio frequencies, mostly below 470 MHz (Haug 2007). Thus, for operators, such as the Bundespost (DBP) or Direction Générale des Télécommunications (DGT), the potential to grow markets offered an incentive to invest in R&D for new analog standards developed at home. For manufacturers, such as Siemens or Alcatel, the development of mostly proprietary and incompatible standards for these growing networks offered an incentive to lock-in home markets and to export to friendly markets. This situation reveals that, in Western Europe, both operators and manufacturers had similar economic interests with regard to the development of wireless technologies, which was mostly inward looking and maintained the vertical relationship between operators and manufacturers.

However, the situation was different across the Scandinavian states – Denmark, Finland, Norway and Sweden – where a combination of both network coordination and frequency harmonisation across borders was taking place in the early 1980s. In fact, since the early 1970s, the Nordic PTTs[68] met in the Nordic Mobile Telephone Group (NMT Group), an association of PTT representatives from the four countries, in order to discuss "issues of a commercial or operative nature" (Haug 2002a: 101). The initial aim of the association was not coordinating telecommunications networks and, most certainly not coordinating standardisation of telecommunications systems. As T. Haug, Secretary of the NMT Group, recalls "the committee's mandate was extremely vague because most of the PTT heads themselves did not understand much about mobile communication technology or uses" (Haug 2002a: 102). As Haug recalls, the main aim was to "obtain common system solutions", which essentially translated into a number of properties that national cellular networks should have in order to sustain other commercial relations between the four members states of the NMT Group (Haug 2002a: 102). Fulfilling these commercial relations was central to the particular development of

[68] This chapter will use the term PTT to refer to telecommunications operators in the Nordic countries. It should be noted, however, that the term PTT is a misnomer for some of the Nordic telecommunications operators/administrations, such as Norway and Sweden, where postal and telecommunications authorities were never connected. However, for the purpose of being succinct in the description of events, the term PTT will be used to refer to all telecommunications operators/administrations. A similar approach was used by Haug (2002).

wireless communications in the NMT Group. The dispersed nature of settlements and the strong economic ties across the Scandinavian region made cross border mobility an essential component of stable commercial relations. The four PTTs had previously deployed wireless systems, most of which were mobile terminals placed on commercial vehicles. These systems used incompatible technologies and were assigned to different radio frequencies, so signals were lost when commercial vehicles travelled across borders. Cross-border roaming was thus a desirable feature of any coordination agreement in the NMT Group (Haug 2002a: 102, Manninen 2002).

Subsequently, the focus of the NMT Group switched to frequency harmonisation. If cross-border frequency harmonisation could be agreed, then an international rather than a national cellular system could be built "in keeping with the usual policy of the PTTs, [...] to define interfaces between building blocks in the system and between the system and the [fixed] telephone network" (Haug 2002a: 102). Essentially, this meant that instead of designing a network for a national frequency one would design a network for a regional frequency – i.e. a larger frequency pool with a single system rather than a system of multiple parts coordinated, if at all, at national borders.

Frequency harmonisation in the NMT Group was achieved successfully in the 1970s. The small number of PTTs, as well as their homogenous economic interests in facilitating cross-border communications to fulfil wider commercial ties, led to spectrum harmonisation in the 450 MHz band. This aligned the preferences of the Scandinavian PTTs for a single wireless cellular network to be deployed across borders. Undoubtedly, however, a single international network was not the preferred option for at least some equipment and infrastructure manufacturers, who would have to compete across borders for the production of network components, rather than to secure national contracts for the production of entire networks at home. Three strategies were adopted in the NMT Group to mitigate positions between operators and manufacturers in order to create a single network in the harmonised 450 MHz band. First, the NMT Committee established a procedure by which each operator was allowed to suggest a number of manufacturers with whom to deliberate system specifications and, later, tenders (Lehenkari and Miettinen 2002: 117, Manninen 2002: 111)[69]. Second, by enlarging the

[69] Initially, the NMT Group convened all interested manufacturers. However, these were not willing to share R&D collectively, so the Group conducted individual hearings from representatives of six manufacturers selected to provide consultation on the

frequency pool across borders, manufacturers of specific network components would benefit from a wider market albeit in conditions of increased competition. Third, in order to prevent intellectual property disputes and, indirectly, to limit the immediate effect of increased competition, the network would use established technologies and techniques that would maintain position in the market (Haug 2002a: 103).

This configuration realigned the economic interests of manufacturers in favour of creating a single network in a harmonised frequency band, which ultimately led to the development of the NMT standard[70] for analog mobile communications – one of the most successful "first generation" standards of radio communications in the world. In addition, it led to the creation of the first network to have international roaming and to occupy a harmonised frequency band, which put forward an alternative institutional arrangement for the governance of radio frequencies across borders.

Therefore, compared with the situation in Western Europe, where radio frequencies were fragmented in incompatible networks along national border, the NMT Group created a common frequency pool in the 450 MHz band as well as a common set of operational rules to harvest the pool, based on the NMT standard. This point requires further analysis as to the distribution of rivalry and excludability in the 450 MHz band. The NMT project has been previously described as "operator-driven cooperation" because it challenged conventional production relations based on lock-in effects (Lehenkari and Miettinen 2002). Instead, the argument goes, the NMT system instilled competition between equipment manufacturers at every component level of the network. While this last point is undoubtedly true, the description of the relationship between operators and manufacturers in this case is possibly less accurate. As Berggren and Laestedius (2003) noted, this relationship did not follow "the user-producer constellation in the conventional sense", but the logic of a "development pair" (2003: 97). The most iconic development pair at the time was Ericsson (manufacturer) and Televerket (public operator in Sweden), who formed a joint venture called Ellemtel in order to develop fixed telecommunications systems. The AXE digital switch, developed

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practical system, both technically and economically. The selected manufacturers were Ericsson, AP, Sonab, STK, Storno and Tekade, originating from the Scandinavian countries and Germany (GFR).

[70] Note that, as mentioned in *Chapter 2*, wireless communications standards are compatibility standards that clarify relationships (or interfaces) between network components, rather than product standards per se.

jointly and produced by Ericsson, was essential to create a single NMT network in a harmonised band. Without the digital circuit switch, the initial idea to project the NMT network in a similar fashion to a fixed telecommunications network could not have been achieved, increasing fragmentation and making the system less desirable. The example of the Ericsson-Televerket development pair is important because it shows the dynamics of coordination – albeit not without its tensions[71] – between industry segments described in conflict due to vertical and/or lock-in relations. Moreover, the example of this development pair indicates that NMT, as a project, relied on an aligned relationship between operators and manufacturers, which would facilitate the creation of common rules for harvesting the 450 MHz frequency band for wireless communications.

In fact, by 1983, the NMT system had the largest share in the global market for mobile cellular systems (Funk and Methe 2001: 598). Not only did NMT networks increase capacity to approximately 100,000 subscribers by mid 1980s, but also the system was easily exported in other parts of the world. In fact, by the mid 1980s, the Austrian, Benelux and Irish PTTs had all chosen NMT systems for their analog networks, which opened up the possibility of band harmonisation and international roaming among them. This situation put pressures on the German, French and Italian telecommunications industries, which were developing home markets at a slower rate than the Nordic counterparts, while also loosing established markets for their exports abroad. In this context, competition between the two approaches of 'frequency coordination' versus 'frequency fragmentation', with different results to extracting economic value from the radio resource, led to the creation of Groupe Spécial Mobile (GSM) in CEPT in 1982. As it will be outlined below, the two approaches continued to inform preferences in GSM-CEPT, which affected the choice of operational rules – i.e. rules of use and rules of access – on the radio spectrum. Before proceeding with the next section, it is important to highlight that coordination in GSM-CEPT, similar to coordination in the NMT Group described above, did not concern a tragedy of use, misuse or overuse in the spectrum common. Instead, it concerned distributional conflicts over rights of use and

[71] It should be noted that, at the start, Ericsson was not willing to deploy the AXE switch on the NMT system. This is because, as Karlsson noted, AXE was considered "too complex for such a peripheral thing as mobile telephony" (Karlsson and Lung, www.ericssonhistory.com). Televerket convinced Ericsson to use AXE, by warning that, otherwise, it would place the order with Ericsson's competitors (Hagstrom qtd in Karlsson, www.teliasonerahistory.com).

rights of access onto a newly created regional pool in the 900 MHz frequency band in Western Europe.

3.2 The Process of Private Rule-Making in the 900 MHz Band

This section follows the process of negotiating a set of operational rules – rules of access and rules of use – to be used in the 900 MHz band for the production of mobile cellular telecommunications. In 1982, the Dutch PTT, with the backing of the Nordic PTTs, proposed the creation of a mobile cellular network to run across Western and Northern Europe and to resemble the NMT network in both operation and function. The proposal was put forward in the CEPT, which, as indicated above, was the preferred setting for voluntary coordination in radio spectrum and telecommunications policy across Europe. This first move by the Dutch and Nordic PTTs triggered a response from their European counterparts, who agreed to set up a group of expert representatives from the eleven PTTs interested in coordinating – albeit at varying degrees – mobile telecommunication networks across Europe[72]. The group – named Groupe Spécial Mobile (GSM) – was to follow the established consensus rules of decision making in the CEPT. Hence, at its origin, GSM-CEPT was designed to replicate the NMT Group, and to allow for negotiations regarding different levels of harmonisation of mobile telecommunications services. These levels of harmonisation were not pre-determined. The following sub-sections explore this process of bargaining in GSM-CEPT for defining different levels of harmonisation and network development in the 900 MHz band. A close analysis of the economic interests and capabilities of members reveals that GSM-CEPT was an association of members with similar interests and relatively equal technology resources, which slowed negotiations based on consensus decision-making. This section concludes that GSM-CEPT was a club of equal members, whose operation relied on exclusive access based on the geographic representation of its members and on the proportional contribution of these members to the technology system used to harvest the common 900 MHz pool.

[72] GSM-CEPT was constituted of PTT members from the following eleven countries: Denmark, Finland, France, Germany (FRG), Italy, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom.

3.2.1 Negotiating Rules of Access

In 1979, the World Administrative Radio Conference of the ITU (WARC 79) designated a part of the 900 MHz band for land mobile communications in Region 1 of the Radio Regulation – the radio region that also includes Europe. Recalling that the radio spectrum is allocated at international level by communications service, rather than by sovereign state (revisit *Chapter 1*), this allocation was made primarily because the band was unused at the time (Haug 2004: 155). However, in the established practice of the ITU Radio Regulations at the time, this allocation did not make reference to a particular technology configuration or telecommunication system to be deployed in the 900 MHz band. More so, the allocation did not specify any level of coordination at regional level other than respect for the principle of basic interconnection and non-interference.

T. Haug, representing Televerket, recalls that PTT representatives discussed this allocation at the CEPT Telecommunication Meeting of June 1982 (Haug 2004: 155). European PTTs already using NMT[73] in the 450 MHz band had a clear economic interest in utilising the 900 MHz band to extend the current system and to harmonise it across borders, which would have eliminated costs of interconnection with other incompatible systems. However, geography stood in the way. The French and German markets, operating incompatible systems other than NMT, were limiting the potential for international roaming in Western Europe. As a result, at the Plenary Assembly of CEPT in Vienna, June 1982, the Dutch PTT made a proposal for:

> "the creation of some kind of harmonised public automatic mobile service in Europe, operating in the 900 MHz band and which would have to be operational in the 1990s" (GSM Doc 3/82: para 5).

The reasons behind the proposal evoked the fragmentation of analog mobile networks in Western Europe (GSM Doc 3/81: para 3). The proposal, which came from the Dutch PTT, should not be surprising. In 1982, the Dutch and Danish PTTs were the first telecommunications operators in the EC to adopt NMT. The proposal received immediate backing by the four Nordic PTTs, recommending that the task of organising "some kind of harmonised public automatic mobile service" should be entrusted to a

[73] Recall that, in addition to four Nordic PTTs, the Austrian, Benelux and Spanish PTTs had also purchased and deployed NMT.

new study group – Groupe Spécial Mobile (GSM-CEPT[74]) – within the Harmonisation Committee of the CEPT (GSM Doc 4/82). T. Haug, former secretary of the NMT Group, was soon proposed and appointed Chairman of the GSM Group.

Having both non-EC and EC members supporting the proposal put pressure on the French and German PTTs to consider participating in the GSM Group. In addition, as long as the mandate of the group did not make reference to a specific technology configuration to be deployed in the 900 MHz band, the group could work as a mechanism for monitoring research and development undergone by competitors. T. Haug, newly invested Chairman of GSM-CEPT, recalls that:

> "The decision only mentioned "harmonisation" which indicates that the compatibility aspect was the dominant factor behind the decision, and few delegates […] sincerely believed that free circulation of radio users across international borders could be achieved" (Haug 2004: 155).

Although informed by competition, the decision to participate in a process of harmonisation established some ground rules for the collective operation of the frequency pool at 900 MHz. The most important was defining the boundaries of the frequency that would motivate group members to invest in further rules of use.

As *Table 3.2* outlines, negotiations about frequency capacity limits and preferred systems to harvest the 900 MHz band were discussed as early as December 1982, a few months after the creation of GSM-CEPT.

These negotiations revealed that interconnecting incompatible telecommunications networks in a harmonised frequency would be too costly for members to establish and maintain. As Haug noted:

> "It soon became obvious, however, that a very wide range of parameters would have to be identical in all participating networks if the system were to be successful" (Haug 1988: 455).

[74] Note that GSM is used to refer to both Groupe Special Mobile (the expert group) and Global System for Mobile Communication (the standard that emerged from the expert group). In order to distinguish between the two, the group will be referred to as GSM-CEPT, while the standard will be referred to as GSM.

Table 3.2 Review of Official Position on Assignment of Mobile Cellular Systems, Selected GSM-CEPT Members, Dec 1982

PTT Members GSM-CEPT	Official Position on Assignment of Mobile Cellular Telephony in the 450MHz and 900MHZ bands
Belgium	Sufficient spectrum capacity in 450MHz band for a modified NMT system until the mid 1990s
Denmark	Insufficient capacity in 450MHz band for NMT system, plans for expansion of system in the 900MHz band from mid to late 1980s
Finland	Sufficient capacity in 450MHz band for NMT system to suffice until early 1990s
France	Need for new system deployed in 900MHz band as only possible solution from mid 1980s
Germany	Sufficient capacity in 450MHz band for System C by the mid 1990s
Italy	Sufficient capacity in 450MHz band for RMTS system until the mid 1990s
Netherlands	Sufficient capacity in 450MHz band for a modified NMT system until the mid 1990s
Spain	Sufficient capacity in 450MHz band for NMT system
Sweden	Insufficient capacity in 450MHz band for NMT system, plans for expansion of system in the 900MHz band from mid to late 1980s
UK	Need for interim system deployed in the 900MHz band, subject to mutual agreement between two service providers in competition

Source: Based on Report from Meeting 1 (1983), CEPT-CCH-GSM, GSM 52/83

As a result, the Dutch and Nordic PTTs proposed a number of broad system specifications to be discussed in GSM-CEPT (GSM Doc 3/82). In fact, these specifications indicated the technology to be adopted for harvesting the 900 MHz band for the production of cellular communications. The proposed rules were (GSM Doc 3/82, Haug 2002c):

- fully automatic system
- roaming capacity
- switching call-in-progress
- high degree of frequency efficiency
- small cell structure (where necessary)
- digital speech transmission
- data transmission
- facilities comparable to the Public Switched Telephone Network

If adopted by all members, the rules would have limited access onto the 900 MHz resource to those following these specifications. Thus, every member of GSM-CEPT had a clear economic interest in defining system specifications that reflected their investments in wireless telecommunications technology. Without a doubt, these system specifications were patterned on the NMT standard (Haug 2002a, Haug 2004). Because of NMT's success, the broad system properties did not raise major distributional concerns among GSM-CEPT members. In fact, there was only one item – the digital speech transmission – that raised distributional concerns, particularly with the French and German PTTs. At that time, all cellular communications using radio frequencies, including the NMT network, used analog speech transmission. Introducing digital speech transmission into the broad network specifications put technical development into system specifications for the network to be deployed in the 900 MHz band. This meant that, rather than defining rules of access for a wider resource pool, the activity in GSM-CEPT would involve redefining rules of use inside to the pool, a situation that caused concern for some GSM-CEPT members. This item would upset the level of rivalry among GSM-CEPT members, by altering the proportional use of technology capabilities for wireless networks to be deployed inside the regional pool. The next section explores in more detail how negotiations among members with relatively equal technology capabilities led to the creation of weak rules of managing use for extracting economic value from the 900 MHz frequency band across Western Europe.

3.2.2 Negotiating Rules of Use

The proposal to include technical development into system specifications changed the nature of activity in GSM-CEPT, making it resemble a standardisation association[75] (Bach 2000). Whereas competition between members drove them to agree on the creation of a regional frequency pool, it prevented them from agreeing on joint technical development for system specifications in the 900 MHz band. As a result, and following consensus decision-making in the CEPT, the members removed "the digital speech transmission" requirement from the system specifications and kept it only as a working assumption, on the basis that digital speech would use spectrum more efficiently than analog speech (GSM Doc 53/83). The removal of this specification reflects the competitive position and equal weight of each member in GSM-CEPT. Besides, it

[75] As mentioned in *Section 3.1*, the main task of the CEPT was the harmonisation of existing networks and, if necessary, of radio frequencies, rather than the development of standards.

shows how competitive considerations between members informed the choice of operational rules in the 900 MHz band.

As early as 1981, the Nordic PTTs announced work on the development of a "digital speech solution" for the NMT network. The project, entitled FMK[76], had roots in previous research run by Televerket and Ericsson (Bekkers 2001: 277, Manninen 2002: 101). The same year, delegates of the French DGT visited Televerket to test the NMT system and were informed of its work on a fully digital system for mobile communications using TDMA access technology for the speech transmission[77] (Dupuis 2002a: 24). Undoubtedly, this development informed the choice of "digital speech transmission" in the initial system specifications for GSM (GSM Doc 3/82).

This development also informed the decision of the French and German operators (DGT and DBP) to sign a cooperation agreement, in July 1983, to coordinate research and development for a new system to be deployed in the 900 MHz band (Dupuis 2002a: 24). The cooperation agreement would forward development for an alternative to the system designed by the Nordic PTTs. It would also ensure that the technology to be jointly developed would be channelled through GSM-CEPT in order to receive early acceptance by all members (Bekkers 2001: 277, Dupuis 2002a: 25). Lastly, contracted manufacturers would design both analog and digital speech systems in order to ensure that both working assumptions in GSM-CEPT would be covered.

Against this background, the GSM-CEPT members agreed to open proposals for system development at the end of 1984 and test them, within the framework of GSM-CEPT, at the end of 1986. However, soon after, the French DGT and German DBP altered the cooperation agreement to refer exclusively to "joint experimental work in digital cellular technology" (GSM Doc 76/84). The Annex to the Agreement specified that "the German part has proposed to give up the idea of introducing one of the proposed analog

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[76] In translation, the abbreviation stands for Mobile Communication of the Future. Originally, the research project was looking at digital FDMA transmission, but soon realized that TDMA technology was more effective. See footnote below for definition.

[77] There are three recognised technologies used in mobile communications for transmitting voice and data: FDMA (Frequency Division Multiple Access) which was used in analog speech and assigns each call to a frequency; TDMA (Time Division Multiple Access) which assigns each call a portion of time on a designated frequency and hops calls periodically; CDMA (Code Division Multiple Access) which assigns a code to each call and spreads it over all available frequencies. TDMA and CDMA are used in digital transmission.

systems and to give preference to the development of proposed digital systems" (GSM Doc 76/84). The decision of the German operator reflected delays in development work on analog systems by the main contracted parties to the agreement – Alcatel and Philips – whose proposal, called MATS-E, was estimated for delivery only towards the end of 1985 (Charlish 1982). Thus, the French and German operators abandoned the analog system solution and opened proposals for digital speech technologies covering all types of access techniques – TDMA, CDMA and FDMA – as well as narrowband and wideband channel systems[78]. In addition, the two operators agreed to provide the technology, free of charge, to any third party in GSM-CEPT:

> "If certain interfaces or transmission methods are chosen as standards by CEPT, and if elements concurring to the definition of those interfaces or transmission methods have been subject to an "essential patent", registered by the contractor during the contract or beforehand or afterwards, a non-exclusive free of charge operating license from the contractor shall be granted to any competent third party of European countries being represented in CEPT that would wish either to produce equipment referring to these standards or to se1l them or also to use them" (Franco-German Experimental Program, Annex C, para 2)

This provision was, in fact, an incentive put forward by the French and German operators for other members in GSM-CEPT to adopt their technology. Were the others to select one of their transmission methods as components for the future network, then the technology will be provided free of charge[79]. As a consequence, the development work undertaken under the Franco-German experimental programme attracted interest from operators in Italy and the United Kingdom, who offered to join the programme in exchange for access to their existing research (Quadripartite Agreement, Annex A and Annex C). Thus, in June 1985, the Italian telecommunications operator Società Italiana per L'Esercizio Telefonico (SIP) joined the Franco-German Programme, followed in April 1986 by Racal-Vodafone and Telecom Sucuricor – the two operators of mobile networks in the UK. The cooperation agreement, known as the Quadripartite Cooperation Agreement (1986), tied together the four operators of the largest telecommunications markets in Europe. The Agreement, based upon an exchange of all

[78] Narrowband and wideband communications refer to the frequency range (bandwidth) chosen to transfer voice and data. Narrowband is generally thought to have better noise levels. Wideband, however, is generally thought to support better data transfer and achieve higher economic performance.

[79] As will be discussed in *Section 3.3*, this provision was also the cause of major instability after GSM MoU (1987) was signed.

registered essential patents related to the technology to be used in the 900 MHz band (Annex C), represented a counterweight to the development activity of the Nordic operators.

Consequently, eight competing proposals were put forward for trial in GSM-CEPT in December 1986 (*Table 3.3*). Four of these proposals were funded by members of the Quadripartite Cooperation Agreement and offered a wide range of access techniques for digital speech transmission, including narrow and wideband solutions. The other four proposals were funded, directly or indirectly, by members of the NMT Group and offered a single access technique for the digital speech transmission – TDMA – as well as a single channel solution – narrowband. Each of the four systems was tested against the original system specifications agreed within GSM-CEPT (GSM Doc 52/83, GSM Doc 73/85).

Table 3.3 Competitive Proposals for GSM Trials in 1986

System	Developers	Main Access Technique	Key partnerships
CD-900	Alcatel/SEL/AEG/SAT/ Italtel	Wideband TD/CDMA	SEL (former ITT subsidiary) sold to CGE/Alcatel in 1986 & SAT part of Alcatel group
MATS-D	Phillips	Hybrid narrow/wideband FD/ TM/CDMA	Phillips through TeKaDe/TRT subsidiaries
S 900-D	ANT/Bosch	Narrowband TDMA	ANT acquired by Bosch in 1992
SFH 900	LCT	Narrow/Wideband CD/TDMA with frequency hopping	Lab Central de Telecommunications France, subsidiary of Matra
DMS-90	Ericsson	Narrowband TDMA	Ericsson acquired Marconi share of SRA (radio systems) and Magnetic (base stations) in 1983
MAX	Televerket	Narrowband TDMA	In partnership with ERA labs
-	Nokia	Narrowband TDMA	
ADPM	Elab	TDMA	Project sponsored through FMK project

Source: Based on Arnold et al (2008), Bekkers (2001: 288), Dupuis (2002a: 27)

The results of the Paris trials revealed that ADPM scored the highest against the initial system requirements, especially against the spectrum efficiency requirement (GSM Doc 23/86, *Table 3.3*). T. Haug explains that ADPM – the system proposed by the Norwegian research centre Elab – was chosen because it offered the most affordable interface solution to the established telecommunications infrastructure available in each member of GSM-CEPT (Haug 2002c: 21, Bekkers 2001: 290). Although ADPM was the technology that scored the highest against commonly agreed system specifications, the French and German operators blocked its adoption for the 900 MHz band. Not only was ADPM a technology developed outside the Quadripartite Agreement and the EC, but the research centre Elab also carried a close history of cooperation with the Swedish operator Televerket[80]. However, T. Maseng (2004), the project director at Elab, noted that narrowband TDMA was selected because it proposed the most cost effective speech solution for both densely and sparsely populated areas in each country represented in GSM-CEPT (2004: 163). P. Dupuis (2002a) recalls that there was considerable agreement in GSM-CEPT over narrowband TDMA as the preferred speech transmission for less costly networks (2001). In fact, the German operator expressed support for the technology (Dupuis 2002a). According to Maseng (2004), the most attractive aspect of the technology was its "adaptive digital phase modulation", a technique that would require the least alterations and, implicitly, reduced costs to adapt the existing telecommunications infrastructure in both rural areas and large cities[81] (2004: 163).

The situation reached a deadlock in February 1987 at the Madeira Conference of GSM-CEPT. Then, all members, bar the French and German operators, declared "narrowband TDMA had substantial advantages over wideband TDMA" and invited their French and German counterparts to reconsider their position by May 1987 (GSM Doc 46/87, para 5). In the meantime, they also adopted the technology as a working assumption for the system to be commonly deployed in the 900 MHz band (GSM Doc 46/87, para 6). The deadlock was broken in May 1987 with the Bonn Declaration of the Quadripartite Cooperation (1987). The Declaration stated that narrowband TDMA was to be adopted as the standard for speech transmission in the 900 MHz band, if enhanced with a delay equalisation modulation technique developed by the CD-900 consortium funded by the French and German operators (*Table 3.3*):

> "Europe must have a single standard supported throughout the CEPT. This should be based on the narrowband TDMA concept defined by CEPT at its Madeira meeting in February 1987, enhanced in the area of modulation and coding to provide the greatest flexibility in receiving equipment implementation" (Bonn Declaration, 1987)

[80] In fact, Elabs development work on the digital speech system was commissioned through the FMK project developed by Televerket and other in the NMT group in 1981 (Manninn 2004:192).
[81] In contrast, CDMA was best suited for densely populated areas.

The Bonn Declaration reflects the trade-offs between industrial actors, with relatively equal technology capabilities, represented in GSM-CEPT. On the one hand, the system to be used in the 900 MHz band was to reflect the equal contribution of those that invested in research and development towards the standard. As T. Haug noted, "even those who were in favour of ADPM found that the change to GMSK [the original modulation technique in ADPM] was a small price to pay for European unity" (Haug 2002c: 22). On the other hand, the Bonn Declaration requested that the agreement were "formalised in a Memorandum of Understanding open to all authorised operators in CEPT" (Art 4), but modelled on the shared intellectual property agreement of the Quadripartite Cooperation (Art 9). Effectively, this ensured that intellectual property would be shared on favourable terms in the GSM MoU (1987) or, more specifically, that "the signatories shall coordinate their policies on intellectual property rights as far as possible" (Art 9, GSM MoU 1987). Fifteen mobile operators, all members of GSM-CEPT, signed the GSM Memorandum of Understanding on September 1987. The GSM MoU (1987) stated:

> "The signatories shall support the open (non-proprietary) definition of at least the following interfaces in the form of CEPT recommendations:
>
> Mobile/Base Station (air interface) based on the narrowband TDMA concept defined by CEPT [...] enhanced in the areas of modulation and coding [...] as agreed by CEPT GSM at its Brussels meeting June 1987
>
> Base Station/Mobile Switching Centre
>
> Mobile Switching Centre/Mobile Switching Centre/Location Register" (GSM MoU 1987, Art 5)

Essentially, the agreement reconfigured network specifications so that the technology deployed in the 900 MHz band would reflect, at least in part, the capabilities of all actors who invested in technical development for GSM. In addition, agreeing to tender on "coordinated intellectual property rights" (Art 9, MoU 1987) was aimed at lowering rivalry between members of GSM-CEPT, while sharing the economic benefits derived from using a single technology system to harvest the 900 MHz pool. These specifications turned GSM-CEPT into a club of industry actors that defined rules of use of the radio resource at 900 MHz based on the contribution of technology capabilities by most of its members, leading to a complex technical standard, while limiting access to this regional pool on technology as well as geographic considerations (GSM-CEPT). However, formalising these complex operational rules of use and access onto the 900 MHz band in a voluntary Memorandum of Understanding (MoU) did not create strong internal mechanisms for monitoring the license-free/patent exchange agreement on which rules of use in the 900 MHz band were based. Also, the MoU did not create strong exclusion mechanisms for controlling entry by new members with limited interest in maintaining the rules that GSM-CEPT members had invested in. The next section explores the impact of this type of interest association on the property arrangements that emerged from GSM MoU (1987).

3.3 The Impact of Private Association on the Choice of Property Systems

This section discusses the impact of the GSM MoU (1987) on the configuration of property arrangements in the 900 MHz band across Western Europe. As a voluntary agreement between fifteen telecommunications operators in Western Europe, the GSM MoU (1987) had limited authority to monitor and enforce commitment to procure digital mobile cellular networks for the 900 MHz band as specified in GSM-CEPT. In 1988, the GSM MoU signatories issued a set of specifications for tendering to manufacturers with the requirement that their essential patents will be provided on a free license to GSM MoU signatories inside or outside of Europe (Art 9). This requirement mirrored the intellectual property agreement of the Quadripartite Cooperation (1986) and represented the trade off put to the French DGT and German DBP in exchange for support of the system specifications agreed upon in GSM-CEPT. Whereas this procurement procedure had the effect of limiting rivalry between operators, with equal technology capabilities and with equal investments in the development of new harvesting technologies for the 900 MHz band, it also had the effect of increasing rivalry between operators and manufacturers as equal beneficiaries of mobile communications derived from the use of the band. This situation destabilised the GSM MoU (1987) and resulted in the elimination of the clause for the provision of free licenses for essential patents. The elimination of the clause followed from signing a cross-licensing scheme between the main manufacturers that participated in the GSM trials (1986). This approach led to a realignment of positions in favour of the GSM system to be deployed in the harmonised frequency pool at 900 MHz, reducing uncertainty over resource rents for both operators and manufacturers and allowing the GSM project to be implemented. However, with the cross-licensing agreements in place, operational rules of use in the frequency pool had changed because the value of the patents held by different members was no longer equal. This situation revealed the weakness of collective choice rules of management and exclusion for the deployment of GSM in the 900 MHz band, as stipulated in the GSM MoU (1987). As a result, the European Commission, as a transnational public actor, intervened to stabilise the system in two ways. First, it proposed the GSM Directive (87/372/EEC), which offered certainty to manufacturers by reserving the frequency bands at 900 MHz for digital mobile communications, albeit without specifying technology requirements for them. Second, it backed up the creation of consortia between operators and manufacturers to jointly develop and distribute the GSM system. The result of these interest realignments in the GSM MoU (1987) led to the creation of property arrangements based on exclusive individual property inside the 900 MHz pool, in order to counterweight the limited authority of the GSM MoU (1987). Thus, although industry actors were the first to define operational rules of access and use of the 900 MHz band at transnational level, these operational rules were not reinforced by collective choice rules of internal management and exclusion, which destabilised the original GSM-CEPT system. In this context, the regulation of the 900 MHz frequency pool in Western Europe was defined by private actors in negotiations of technical systems, but the monitoring and enforcement of the property rules resulting from these negotiations did not rest with the private actors but with the public actor.

3.3.1 The Nature of Private Association

The GSM MoU (1987) committed its signatories to provide public commercial services for digital mobile communications in the 900 MHz band by 1991, based on the assumption that intellectual property rights essential to the GSM system would be provided on a free license to all signatories of the agreement. T. Haug confirmed that standardisation work in GSM-CEPT was premised on the assumption of developing an open standard, whereby the use of patented technologies was avoided unless they were provided royalty-free to all members (Haug 2004: 157)[82]. Temple (2002) explains that “coordination on intellectual property rights” was kept in the original MoU (1987) because the Quadripartite signatories had shared intellectual property from the start of

[82] The Quadripartite Agreement (1986), partly mirrored in the initial GSM MoU (1987) at the request of the Quadripartite Agreement signatories, took this clause further by requesting that essential patents chosen as standards be made available free of charge, on a non-exclusive basis, to third parties of European operators (Annex C, Quadripartite Agreement).

the GSM programme and, under different circumstances, would run the risk of sharing their patents royalty-free without a reciprocated commitment from other GSM MoU signatories (Temple 2002: 45). Bekkers, Verspagen and Smith (2002) explain that this approach was common practice when monopolist network operators – i.e. the PTTs – determined and funded the development work of manufacturers in exchange for long-term contracts, which sometimes included "licensing patents to other suppliers at no costs by operators with multi-supplier policies" (Bekkers et al 2002: 1144).

Originally, this situation was not contested by the main manufacturers that participated in the GSM Paris trial (revisit *Table 3.3*), because the GSM MoU (1987) opened the possibility of a considerably larger market as a result of the harmonisation of the 900 MHz frequency pool. Indirect commitment to the GSM MoU (1987) was also secured by the intervention of the European Commission, which proposed the GSM Directive (87/372/EEC) that reserved and harmonised the frequency pool at 900 MHz for the "introduction of public pan-European cellular digital land-based mobile communications in the European Community". Although Council Directive 87/372/EEC did not specify the technical parameters of the system to be deployed in the 900 MHz band[83], it referred to the work carried out by GSM-CEPT. Thus, Council Directive 87/372/EEC acted as a stabiliser to the creation of the regional frequency pool in the 900 MHz band for those willing to adopt the technical specifications of the GSM MoU (1987). This interest alignment between EU and non-EU operators was also achieved because Finland and Sweden were preparing their accession to the European Union in the enlargement of 1995. The joint commitment to the GSM MoU (1987) and Council Directive 87/372/EEC achieved the lowering of rivalry between operators in the 900 MHz band, allowing unanimous support for the GSM system specifications.

However, the frequency pool created by the GSM MoU (1987) was still susceptible to new entry by outsiders. The main destabiliser was Motorola, acting as a free-rider on the open standardisation process that occurred in GSM-CEPT. A US manufacturer with

[83] The GSM Directive 87/372/EEC stipulates that "for the purpose of this Directive, a public pan-European cellular digital land-based mobile communications service shall mean a public cellular radio service provided in each of the Member States to a common specification [common standard], which includes the feature that all voice signals are encoded into binary digits prior to radio transmission [radio speech transmission], and where users provided with a service in one Member State can also gain access to the service in any other Member States [transnational roaming]" (text in brackets not in the original).

European base, Motorola established several research and development subsidiaries across Europe through the 1980s, due to the strong competition it faced from the private monopoly Bell-AT&T in the US market. However, instead of placing bids for development contract with the GSM-CEPT operators in preparation of the GSM Paris trials (revisit *Table 3.3*), Motorola continued research and development in digital speech transmission for mobile terminals outside the GSM-CEPT framework. This meant that Motorola was not tied into the intellectual property clause of the GSM MoU (1987) and, throughout the late 1980s, patented some of the digital radio technology standardised in CEPT[84]. This technology turned out to be essential to the GSM standard, which determined Motorola to refuse to license it under the royalty-free conditions of the initial GSM MoU (1987).

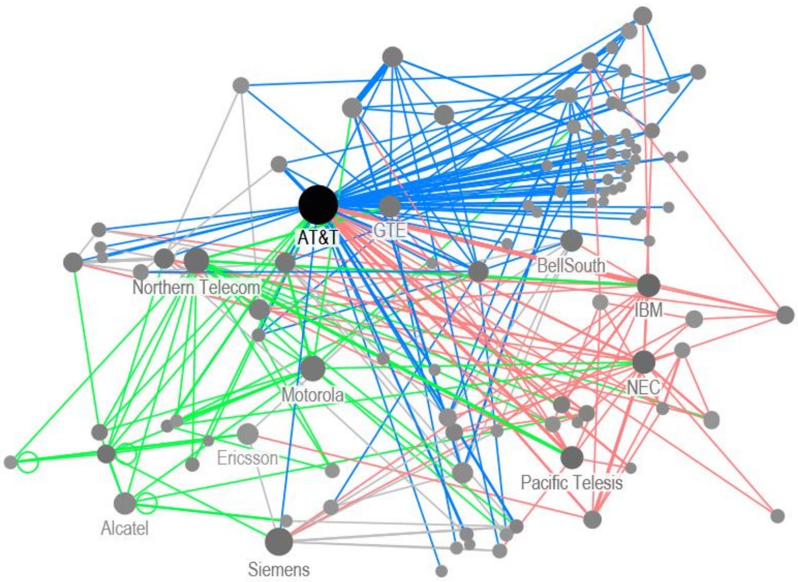
Faced with this stalemate, operators removed the free intellectual property clause from the GSM MoU procurement procedure, but required manufacturers to supply the market covered under the GSM MoU Agreement (1991) on “fair, reasonable and non-discriminatory conditions” (Bekkers, Verspagen and Smith 2002: 1147). Once again, Motorola refused this clause on the premise that it was willing to enter cross-licensing agreements only with manufacturers of complementary products to its terminals (Bekkers et al 2002: 1151). Indirectly, this meant that Motorola was signalling cross-licensing agreements with the main manufacturers of base stations and switches contracted for system development in GSM-CEPT (revisit *Table 3.3*).

This position reflects Motorola’s strategies to use its technology capabilities to tip the degree of rivalry inside the 900 MHz frequency pool in its favour. As a result, from 1990 to 1993, Motorola signed cross-licensing agreements with Alcatel (1990), Siemens (1990), Matra (1991), Philips (1992), Ericsson (1992) and Nokia (1993) (*Figure 3.2*). *Figure 3.2* provides a visual representation of global technology transfers in radio communications from January 1990 to December 1994[85]. It applies a cluster analysis, represented by vertices in different colours. From a visual standpoint, the network

[84] A study conducted by Bekkers et al (2002) confirms that Motorola filed for the largest number of essential patents in January 1987, only a few months prior to the signing of the GSM MoU (1987) and once narrowband TDMA was agreed unanimously as the technology to be used for the radio speech transmission of GSM.
[85] This visual representation applied a filter of the eigenvector centrality at 0.0025, which eliminates one-off transfers of outliers. However, *Table 3.4* gives the main network metrics prior to the application of any visual filters.

representation confirms that Motorola interacted in the same cluster with Ericsson, Alcatel and Siemens (green cluster).

Figure 3.2 Network Visualisation of Technology Transfers, Global Strategic Alliances, Jan 1990 - Dec 1994



Source: Based on Thompson Reuters SDC Platinum Database, Accessed Dec 2013

Figure 3.2 also provides the visual representation of the network metrics in *Table 3.4*. Motorola scores one of the highest degree centralities in a network of approximately 2,700 technology transfer, at DC=30 (*Table 3.4*).

As a representation of the number of exchanges in the network, the high degree centrality logged by Motorola reveals its considerable portfolio in radio communications from 1990 to 1995. As a measure of influence in the network, Siemens, Ericsson and Motorola score high levels of eigenvector centrality at over EC=0.01 (*Table 3.4*), which confirms their position in the global market for mobile communications following the new GSM MoU Agreement (1991), which removed the royalty free license clause and brought in new GSM MoU signatories.

Table 3.4 Network Analysis Metrics, Global Strategic Alliances, Jan 1990 - Dec 1994

Measures	**Network Analysis of Strategic Partnerships Global Telecommunications Sector Jan 1990 – Dec 1994**
No log entries	2,718
No nodes	1,125
Mean degree centrality	2.3
Mean eigenvector centrality	0.001
Mean betweenness centrality	760
Max degree centrality	AT&T (78), Siemens (37), Northern Telecom (30), Motorola (30), IBM (24)
Max eigenvector centrality	AT&T (0.45), IBM (0.016), NEC (0.014), Pacific Telesis (0.014), Siemens (0.013)
Max betweenness centrality	AT&T (95,927), Siemens (29,285), Northern Telecom (27,773), Pacific Telesis (24,584), NEC (23,776)

Source: Based on Thompson Reuters SDC Platinum Database, Accessed Dec 2013

In order to stabilise these new conditions of rivalry and excludability in the 900 MHz frequency pool for the deployment of GSM systems, the European Commission intervened to confirm the legality of the manufacturing consortia that followed from the new procurement procedures, which eliminated the original intellectual property clause from the GSM MoU (1987). In COM Decision 90/446/EEC, the European Commission decided that these consortia “do not have as its object or effect the restriction of competition within the common market”, because “the development and manufacture of the GSM system is so great that realistically there is no scope for companies to act individually” (COM Decision 90/446/EEC, para 2). This last step confirmed the new operational arrangements in the 900 MHz band, based on limited rivalry among manufacturers but increased rivalry between manufacturers and operators of GSM systems. This last step also confirmed the necessity of an external public actor to intervene in order to stabilise new operational arrangements in the absence of internal mechanisms of mutual monitoring and exclusion inside the GSM MoU. The next section summarises the configuration of property arrangements in the 900 MHz frequency pool across the CEPT in the late 1980s and early 1990s, discussing the relationship between the distribution of interests and capabilities among members of GSM-CEPT, later GSM MoU, and the resulting operational and collective choice rules established to extract value from the band.

3.3.2 The Nature of Property Arrangements in the 900 MHz Frequency Pool

The negotiation and renegotiation process of the GSM MoU (1987) reveals important considerations about the relationship between the configuration of industry actors and the property arrangements that result from their organisation, with the aim to withdraw economic benefit from the 900 MHz frequency band at transnational level. *Table 3.5* provides a summary of the configuration of property arrangements that resulted in the 900 MHz band for the deployment of GSM across Western Europe in the late 1980s.

Table 3.5 The Configuration of Property Arrangements in the 900 MHz Regional Frequency Pool for the Deployment of GSM Systems in the late 1980s

Property Right		**Property Arrangements in the 900MHz Frequency Band based on GSM**
Operational Rights	*Access*	The right to enter the radio resource is granted based on membership in a geographic club (CEPT) and on membership in a technology club (GSM).
	Use	The rate of use of the radio resource by each member is given by the extent to which their technology capability enters into the standard. Initially, in GSM-CEPT, the value of each technology capability represented in the standard was equal. Later, in GSM MoU, the value of each technology capability represented in the standard is given by a cross licensing agreement, arranged outside the authority of the GSM MoU.
Collective Choice Rights	*Management*	Consensus decision-making inside GSM-CEPT provides basis for agreement of operational patterns of use in the 900 MHz band, based on either equal representation of technology capabilities in the standard or based on royalty free access to technology specifications in the standard. However, rights to manage internal use patterns are limited in GSM-CEPT. There are no internal mechanisms for mutual monitoring of rights of use based on fair representation of technology capabilities of members in the GSM standard.
		Cross licensing of technology for harvesting 900 MHz takes place outside GSM MoU. Industry actors require the authority of a public actor to legitimise and to monitor these arrangements, based on market considerations.
	Exclusion	The right to determine who has access to the 900 MHz band is limited in GSM-CEPT. External entrants, such as Motorola, need to be internalised if investments in the initial operational arrangements are to be protected.

First of all, the organisation of GSM-CEPT, in the wider context of consensus oriented decision making in CEPT, shows that industry actors entered GSM-CEPT with homogenous interests in the economic outcome resulting from harvesting the 900 MHz band. The main economic interest was to harvest the resource for a new and wider market for digital mobile cellular communications. The organisation of system development work in GSM-CEPT also shows that industry actors entered it with relatively homogenous capabilities in order to create technology solutions to harvest the resource independently. This relatively equal distribution of capabilities among members of GSM-CEPT kept internal rivalry high, until the free royalty agreement was introduced, which lowered internal competition between members by attributing the same value to all technology specifications that made it into the standard.

This initial distribution of economic preferences and technology resources led to the establishment of a particular configuration of rules of access and rules of use of the 900 MHz frequency band by GSM-CEPT members. On the one hand, rights of access to the 900 MHz band were given by membership in the CEPT as a geographic interest association and by membership in GSM-CEPT as a technology association that developed a particular technical specification for harvesting the radio resource. On the other hand, agreeing on a particular rate of use of the 900 MHz band was difficult to achieve due to the competing relationship between resource users with equal capabilities to develop technology systems, which would achieve their economic interest of harvesting the frequency pool. The rate of use of the 900 MHz band, as embedded in the technology specifications of the GSM standard, was only settled in GSM-CEPT when intellectual property cooperation mechanism was formalised in the Quadripartite Agreement (1986) and Bonn Agreement (1987). This royalty free licensing agreement gave the same value to each technology capability represented in the GSM standard, if adopted to harvest the 900 MHz frequency band (*Table 3.5*).

However, the homogenous distribution of economic interests and technology capabilities among members in GSM-CEPT also revealed problems with the establishment of collective choice rules to safeguard the operational rules of access and use explained above. In particular, the symmetric technology interests of service operators prevented them from establishing an internal mechanism for mutual monitoring, which would ensure commitment to intellectual property coordination, as agreed upon in the original GSM MoU (1987). Also, the interest of members to have their technology capabilities represented in the GSM standard used to harvest the radio resource prevented them from establishing exclusion mechanisms that would protect the association and, implicitly, the resource from entry by non-members, who had not invested in developing common operational rules of access and use to the 900 MHz band (*Table 3.5*).

Subsequently, under the GSM MoU (1987), signatories established limited collective choice rules to monitor the implementation of operational rights agreed in GSM-CEPT. Their limited authority to manage the internal commitments of system manufacturers, and to exclude new entrants, triggered changes to the initial operational rules agreed in

GSM-CEPT. Thus, the intellectual property coordination mechanism – which set an equal value for technology contributions to the GSM standard – was removed from the GSM MoU (1987) and cross-licensing agreements among manufacturers were formalised, outside the GSM MoU. This required the intervention of the European Commission, as a public actor to legitimise the creation of several industry consortia and to monitor their use and access onto the 900 MHz frequency pool, from a competition policy perspective based on communications markets. However, under these new conditions of internal rivalry inside the GSM MoU(1987), the property arrangement in the 900 MHz frequency pool in the CEPT was based on principles of individual exclusive property that would secure individual rights to patented technology for manufacturers and individual rights to the exclusive use of GSM in the 900 MHz frequency pool by operators.

3.4 Conclusions

This case has traced the initiation and definition of operational rules for the 900 MHz frequency band by industry actors in GSM-CEPT and, later, in GSM MoU (1987). The case suggests that industry actors with symmetric economic preferences and equal technology capabilities, such as the PTTs in Western Europe in the late 1980s, can organise to produce operational rules to govern a frequency pool collective, with the aim to extract economic value from its use. The case is relevant because it reveals that industry actors could achieve this initial coordination in the absence of a transnational public actor with established competences in the telecommunications sector, such as the Commission of the European Community. As it is revealed, at the time, the centripetal force of policy making in the European Community, particularly in the field of telecommunications, was limited.

The evidence of coordination among industry actors with relatively homogenous interests and capabilities confirms, thus, theoretical assumptions in the study of common pool resource governance. In this case, PTTs solve the problem of organisation and engage in technology system design in order to define a common set of operational rules for the 900 MHz band. However, in this case, they do not reinforce operational rules for the collective use of the 900 MHz band with stable collective choice rules – i.e. rules of internal management and rules of exclusion. This finding contradicts theoretical expectations of stable collective choice rules in conditions of homogeneity of interests (Agrawal 2003: 249). In our case, PPTs maintain a high degree of internal rivalry over the technology specifications that would be used to harvest the radio resource and do not invest in new mechanisms of internal management, relying on the decision-making structure established in CEPT. This collective choice is particularly problematic because, as discussed in the chapter, GSM was an ad hoc standardisation unit, whereas CEPT was an intergovernmental organisation tasked with policy harmonisation in telecommunications. The limits of internal management are also revealed when the intellectual property coordination mechanism – which established a particular set of rules of use for the 900 MHz frequency pool – is broken following entry by a free rider and the establishment of cross licensing agreements outside the context of the GSM MoU (1987).

Thus, operational rules of use for the 900 MHz band – as established in the GSM MoU (1987) – were challenged, from within, by manufacturers who worked in the development process with the PTTs. Similarly, operational rules of access onto the 900 MHz band were challenged, from without, by manufacturers who developed similar systems privately and were now trying to gain entry. Due to this contestation, internal rivalry among developers and operators of GSM remained high, revealing an actor preference for individual rights of use of the frequency band, coupled with technology and service exclusion, in order to secure investments in the creation of the original pool. Due to these high levels of rivalry and excludability, industry actors relied on the public actor to formalise these property arrangements in Directive 87/372/EEC.

This case contributes to our understanding of dynamics of coordination inside a transnational common pool resource, revealing that homogeneity of interests and capabilities might be sufficient to solve first level problems of organisation and, not always, second level problems of mutual monitoring and enforcement (revisit *Section 1.1.2*). Broadly, it contributes to our understanding of the relationship between authority and rights in transnational common pool resources. While authority for defining operational rules rests with industry actors, monitoring and enforcement rests with the public actor. As long as rules of access and use are contested internally, industry actors will prefer individual exclusive rights to the common pool, legitimised by a public actor.

Chapter 4. Regulating the 1.9-2.1 GHz Band: Devising Collective Choice Rules in Regional Pools

This chapter follows the process of defining property arrangements in the blocks of frequencies between 1,980-2,010 MHz and 2,170-2,220 MHz (hereafter 1.9-2.1 GHz), used for the deployment of third generation mobile cellular communications systems across Europe[86] in the late 1990s. Similar to the previous case study, this chapter reveals that industry actors played an active role in negotiating and defining operational rules of access and use of the 1.9-2.1 GHz frequency bands for terrestrial mobile communications services at regional level. However, the case on the regulation of the 1.9-2.1 GHz bands has two points of difference with the previous case study on the regulation of the 900 MHz band in the same geographic area.

First, this case study reveals a stronger presence of a transnational public actor in the form of the European Commission, who acquired formal authority in telecommunications in the early 1990s. Moreover, this case study reveals that the transnational public actor had a strong technology preference for the evolution of mobile cellular communications in a particular direction, which differed from the technology preference of industry actors. This difference in the position and the technology preference of the transnational public actor is useful in order to test whether, in the presence of a public actor with established policy venues, industry actors will conduct negotiations within these established policy venues or will choose to negotiate in private venues of decision-making. To this end, the chapter reveals that, even in the presence of a transnational public actor with established policy venues and known technology preferences, industry actors choose to negotiate technology configurations that define operational rules for radio frequencies in autonomous and private industry associations, such as European Telecommunications Standards Institute (ETSI SMG).

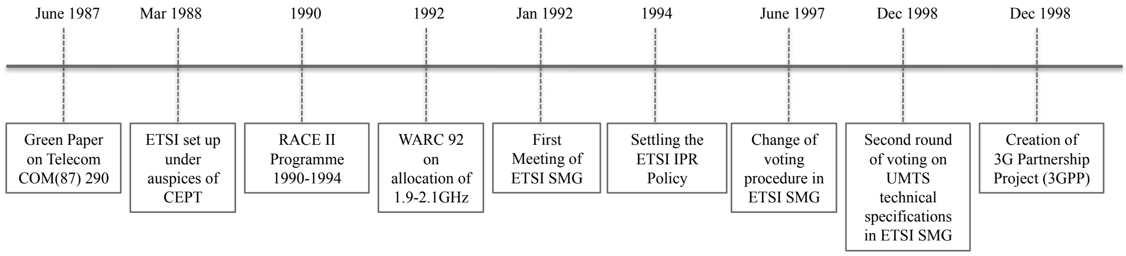
Second, this case study reveals a different distribution of economic interests and technology capabilities among industry actors interested in extracting economic value from the 1.9-2.1 GHz bands. Whereas, similar to the first case study, both service

[86] Note that, whereas in Case Study I, the geographic boundaries of the 900MHz frequency pool are limited to CEPT Member States situated in Western Europe, this case study looks at a wider frequency pool from a geographic point of view, following the admission of new members from Central and Eastern Europe in the CEPT in the 1990s.

operators and system developers have symmetric interests in the economic output derived from harvesting these bands, for the purpose of providing evolved technology systems based on GSM, they have more heterogeneous technology capabilities than in the previous case study, due to the centrality of manufacturers with essential patents in the development of GSM systems. This difference between the first and the second case study is useful in order to test theoretical expectations regarding homogeneity in economic interests combined with heterogeneity in technology capabilities among private actors and the configuration of property arrangements resulting from the negotiations of these private actors. As such, theoretical expectations based on the study of common pool resources would indicate that this combination of interests and capabilities is more likely to impede private cooperation, because of considerable differences in use preferences. Theoretical expectations based on the study of transnational common goods, however, would indicate that this combination of interests and capabilities can lead to private cooperation if those actors with vested interests in a given technology configuration, and with considerable capabilities, are willing to invest in the creation and maintenance of operational rules, which support that technology solution. To this end, the chapter confirms that, rather than impeding private cooperation, this distribution of interests and capabilities can result in the creation of common operational rules of access and use for a new frequency pool around the capabilities of a few developers with considerable technology resources. However, the chapter also reveals the weakness of these collective choice rules when they do not ensure the participation of an important resource user group in system development (i.e. service operators). The chapter also reveals the weakness of commitments to newly defined operational rules, if industry actors do not exchange information about their technology preferences prior to decision-making on the technology configurations that define rights of use in the frequency pool at 1.9-2.1 GHz. In this circumstance, levels of internal rivalry remained high among members of ETSI SMG, even when rules of exclusion were strict, resulting in a property arrangement based on principles of individual exclusive property, similar to the first case study in this thesis.

The chapter is organised in a similar manner to the previous case study, following the process of negotiating technology specifications for deploying third generation mobile communication systems called Universal Mobile Telecommunications System (UMTS) in the regional frequency pool at 1.9-2.1 GHz band (*Figure 4.1*).

Figure 4.1 Timeline of Main Events in the Regulation of the 1.9-2.1 GHz Bands for UMTS Mobile Communications Systems in the 1990s



Similar to the previous case study, the bargaining process between industry actors lasted over a decade. A timeline of main events is introduced to guide the reader through the focal points in the negotiation process, noting that the same analytical framework is applied, which looks first at the position and technology preference of the public actor and, second, at the distribution of interests and technology capabilities among private actors (*Section 4.1*), in order to then trace the bargaining process for deciding operational and collective choice rules in the 1.9-2.1 GHz bands (*Section 4.2*).

4.1 The Formation of Actor Strategies in the Wider Governance of Telecommunications

This section follows the formation of economic interests and technology preferences that informed the strategies of public as well as private actors in the negotiation of operational rules of access and use, as well as collective rules of management and exclusion in the 1.9-2.1 GHz band across the CEPT. In contrast with the case of the regulation of the 900 MHz band in the same radio region (*Chapter 3*), this case reveals a transnational public actor – in the form of the European Commission – with a clear position in the management of telecommunications markets across the European Union, whose geographic reach juxtaposed, in considerable proportion, that of the CEPT. This section also reveals that, beyond exhibiting clear competences in telecommunications policy in the EU, the Commission had a clear technology preference for mobile communications, which was considered revolutionary because it tried to achieve the integration of fixed and mobile communications systems in a single infrastructure and, subsequently, to gradually phase out second generation mobile communications systems based on GSM. However, industry actors deriving considerable economic value from harvesting the 900 MHz band using the GSM system did not share this technology preference. Instead, both operators and manufacturers that deployed GSM across the CEPT, as well as outside the CEPT, were interested in extending and, if necessary, evolving GSM networks to new frequency bands in order to improve the return on investment in these networks following the implementation of the GSM MoU (1991). This section concludes by showing that private industry actors, particularly manufacturers, responded to the revolutionary vision for telecommunications put forward by the European Commission by strengthening private mechanisms of decision-making inside the newly created standardisation body called the European Telecommunications Standards Institute (ETSI), which took over and formalised the standards development process established, ad hoc[87], in GSM-CEPT. Overall, the next section reveals the centrality of a small number of key manufacturers, with essential technology capabilities for the development of second generation (GSM) and third generation (UMTS) mobile communication systems as well as the uncertainty regarding the configuration of UMTS as either an evolution from the GSM core network, which would maintain the existing distribution of rivalry and excludability in the radio resource as envisioned by system developers, or the configuration of UMTS as a new radio component to a core public network, as envisioned by the European Commission.

4.1.1 The Structure of the System of Governance in Telecommunications

The first GSM networks were deployed across Western Europe in 1992[88], following the opening of the GSM Memorandum of Understanding (1991) to operators outside the geographic boundaries of the CEPT. As discussed in *Chapter 3*, the opening up of the GSM MoU (1991) followed from changes in the licensing of intellectual property for the technology essential to the GSM standard[89]. In short, the strategy of

[87] It is important to remember that Groupe Special Mobile (GSM) was not part of the permanent structure of the CEPT. Being a standards development group, it stood apart from the overall scope of the CEPT, which focused on telecommunications policy harmonisation at the time (revisit *Chapter 3*).

[88] Although the GSM MoU stipulated that “the purpose of the MoU is primarily focusing on opening a pan European public service in 1991” (Preamble, GSM MoU 1991), the first GSM networks opened in mid 1992, due to delays in the type approval of mobile terminals used for this service.

[89] The Addendum to the GSM MoU (1991) noted that “in addition to those that meet the requirements of Art 2 of the MoU, the MoU together with this Addendum can also be signed by a telecommunication administration from outside the CEPT member states, or an operator which is authorized in such a country to provide public digital cellular

telecommunications manufacturers to impose fees on proprietary technologies[90] essential to the deployment of digital cellular networks led to a change in the strategy of GSM MoU signatories, who opened the agreement to operators outside the CEPT in order to benefit from greater economies of scale derived from network harmonisation and international roaming (Dupuis 2007).

The effect of the opening up of the GSM MoU (1991) was the creation of transnational economies of scale for network operators willing to commit to the adoption of the technology in their home markets. In addition, the opening up of membership to operators around the world led to the creation of a permanent decision-making structure within the GSM MoU (1991), which became the GSM Association in 1995, totalling over 100 member operators and over 10 million subscribers around the world[91]. The exponential growth of this association of operators translated into a dominant position of the GSM standard in the global mobile telecommunications market throughout the 1990s (*Figure 4.2)*. *Figure 4.2* provides the market shares of the main compatibility standards for mobile telecommunications at global level from the mid 1990s to the mid 2000s. The chart compares the market shares of first generation (analogue), second generation (GSM, TDMA, PDC, CDMA) and third generation (W-CDMA) compatibility standards in mobile telecommunications at global level. The chart reveals that, within a decade, the GSM standard gained considerable lead in the market for mobile telecommunications, increasing its global market share fivefold from approximately 15% in 1995 to over 75% in 2005 (*Figure 4.2*).

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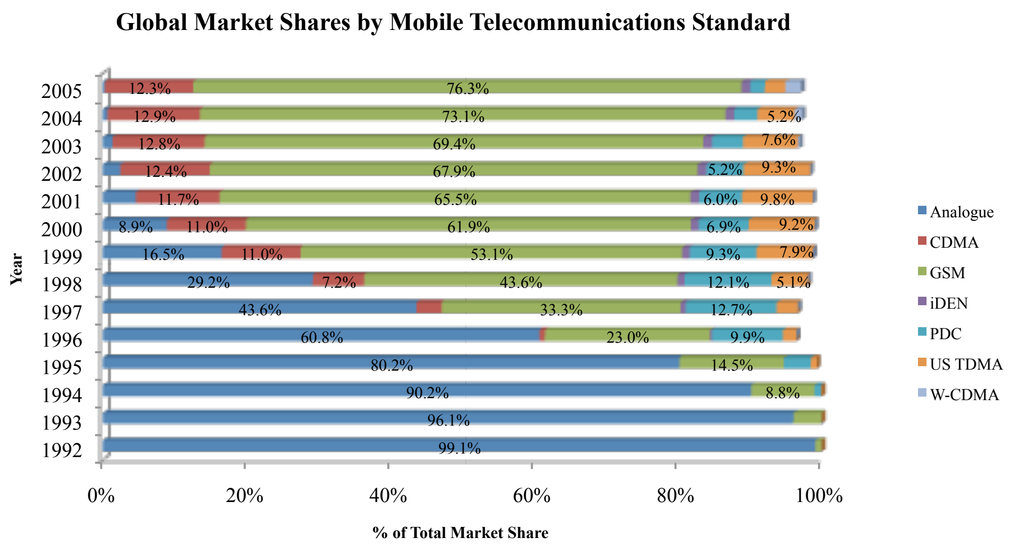
mobile telecommunications services at 900 MHz" (Art 2, Addendum to GSM MoU 1991).

[90] *Chapter 3* shows that, following from the Quadripartite Agreement (1986), the original GSM MoU (1987) stipulated that essential patents chosen for the standard be made available free of charge to other operators members of CEPT as well as to their partners, if outside the CEPT. See *Section 3.3.1*, *Chapter 3*.

[91] The main events in the transition from the GSM MoU (1987) to the GSMA are available at http://www.gsma.com/aboutus/history. The GSMA is one of the largest international associations representing the interests of mobile operators in the world. By 2010, the GSMA represented the interests of operators with over 3 billions connections on GSM networks (GSM History, Accessed 15 January 2014).

Figure 4.2 Market Shares of the Main Mobile Telecommunications Standards at Global Level, 1992-2005



Source: Based on Informa WCIS, Accessed Dec 2012

Inside the European Union[92], mobile telecommunications markets were also growing exponentially and the number of subscribers of second generation mobile telecommunication networks (GSM) increased from just under 10 million subscribers in 1995 to over 180 million subscribers in 2000[93] (*Figure 4.3*). The growth of the mobile telecommunications market provided incentives for both public and private actors interested in harvesting the radio resource for mobile communications products and services. Its most immediate manifestation was a growing demand for space in the radio spectrum to accommodate new subscribers beyond the 900 MHz frequency band reserved for second generation mobile communications in the early 1990s. On the one hand, industry actors were interested in extending GSM networks to new frequency bands in order to improve the return on investment in GSM networks[94]. On this aspect,

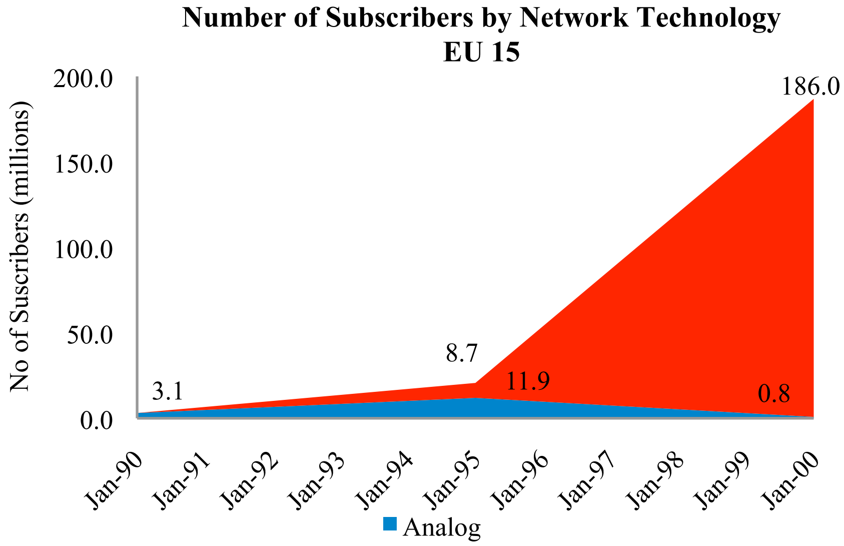
[92] *Figure 4.3* provides estimates of the total number of subscribers of first generation (analog) and second generation (GSM) cellular telecommunications networks in the EU15 comprising Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

[93] The GSMA estimated that, by the end of 2000, GSM network operators had over 400 million subscribers at global level. See Selian (2003: 17).

[94] In 1995, CEPT passed Decision ERC/DEC/(95)03 on the Frequency Bands Designated for the Introduction of DCS-1800, which was later renamed GSM-1800, due to the similarity between the standards. As Selian (2003) noted, GSM specification were

both operators and manufacturers had aligned their economic preferences for populating new frequency bands with existing second generation cellular services (GSM) in order to benefit from the considerable growth potential of the mobile telecommunications markets[95] (*Figure 4.3*).

Figure 4.3 Comparative Growth of Analog and Digital Cellular Mobile Communications Networks in EU15, 1990-2000



Source: Based on Informa WCIS, Accessed Dec 2012

On the other hand, public actors were interested in forwarding the agenda for liberalisation of the telecommunications sector following from, albeit not exclusively, the post-Uruguay round of negotiations on basic telecommunications services of the World Trade Organisation (1994-1997)[96]. For public administrators, the growth of

slightly modified for the higher frequency and, as a result were renamed as DCS. However, in 1997, DCS-1800 was renamed GSM-1800, reflecting the deployment of the GSM system in this higher frequency (Selian 2003: 15).

[95] In 1995, the penetration rate for mobile communications services – analog and digital (GSM) – stood at approximately 5% of the population across members of CEPT situated in Western and Central Europe (Informa WCIS Database, Accessed 15 December 2013). Thus, the market for mobile communications was still at an early stage in its development.

[96] The negotiations, which took place from 1994 to 1997, resulted in a Reference Paper on the main commitments for liberalising telecommunications, adopted by over 50 WTO members, comprising the members of the European Union and wider European Free Trade Association. The main commitments of the WTO Reference Paper on Basic Telecommunications (1997) cover the creation of an independent regulatory body separate from suppliers of basic telecommunications services designated to ensure the transparent and universal provision of services and the prevention of anti-competitive

mobile telecommunications gave the opportunity to apply international commitments of sector liberalisation in the newer mobile communications segment of the market, rather than the traditional fixed telecommunications segment of the market, still dominated by monopoly providers. This position is reflected in the divergent regulatory approaches to second generation mobile communications services across developed telecommunications markets in the world. In Japan, as in Western Europe, public administrators supported aligned industry positions on the development and deployment of a single standard – PDC in Japan and GSM in Western Europe[97] – in a harmonised frequency band, encouraging the creation of economies of scale. By contrast, in the United States, the public administrator supported competition between standards[98] in non-harmonised frequency bands[99], encouraging innovation in systems and networks. These approaches resulted in different growth paths for mobile telecommunications standards at global level (*Figure 4.2*) and, inherently, to tensions between regulating frequency bands for replication or for innovation, with different implications on the dynamics of rivalry and excludability in bands designated for mobile telecommunications services. Thus, underpinning the position of both public and private actors interested in the development of mobile communications markets were

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practices in the sector. Also, the Reference Paper stipulated the procedures for the allocation and use of scarce resource such as radio frequencies on an "objective, timely, transparent and non-discriminatory manner" (Para 6, Reference Paper on Basic Telecommunications). See WTO Telecommunications Services, http://www.wto.org/english/tratop_e/serv_e/telecom_e/telecom_e.htm

[97] Recall that, throughout the development of these standards, public operators had the dual role of administrators and providers of telecommunications services (revisit *Chapter 3*). In this case, an alignment between the public position of telecommunications administrators and industry actors was possible. Thus, similar to how GSM was the single standard adopted across CEPT member states, PDC (Personal Digital Cellular) was the single standard adopted across Japan at the proposal of the NTT public operator in cooperation with Japanese manufacturers. For a detailed account, see Kano (2000).

[98] The Federal Communications Commission (FCC) approved both TDMA and CDMA-based standards for the deployment of second generation mobile systems. For personal communications systems, a variant of second generation mobile systems, there were as many as seven standards available, including CDMA, TDMA and DECT-based standards. For a full list, see Kano (2000).

[99] The Federal Communications Commission (FCC) did not specify a timeline for the rollout of second generation mobile telecommunications networks, meaning that service providers were able to choose the standard and the time when to refarm their licensed spectrum from first generation (analog) networks to second generation (digital) networks.

considerations of growth based on replication of existing services or innovation of new services to be deployed in new frequency bands.

These divergent positions towards radio resource allocation for market growth in mobile telecommunications consolidated two distinct technology preferences for the main public actor and the main industry actors interested in harvesting additional radio frequencies for mobile communications services. The next two sections address the formation of these technology preferences for the Commission of the European Union (European Commission) as a transnational public actor whose jurisdiction overlapped that of the European Conference of Postal and Telecommunications Administrations (CEPT) as well as the formation of technology preferences for the main manufacturers of equipment and infrastructure in mobile telecommunications at transnational level across Western and Central Europe[100].

4.1.2 The Initial Position of the Public Actor

The position of the European Commission as a public actor in the telecommunications sector of the European Union was formalised in the Treaty of Maastricht (1992). The Treaty clarifies the role of the Commission in defining guidelines "covering the objectives, priorities and broad lines of measures envisaged in the sphere of trans-European networks" (Art 129c, para 1). In particular, the European Commission becomes an agenda-setter for "the establishment and development of trans-European networks in the areas of transport, telecommunications and energy infrastructures" (129b, para 1), in accordance with the liberalisation and interconnection of national infrastructures:

> "Within the framework of a system of open and competitive markets, action by the Community shall aim at promoting the interconnection and interoperability of national network as well as access to such networks" (Art 129b, para 2, Treaty of Maastricht 1992).

From this viewpoint, it could be argued that the growing role of the European Commission as a public actor in the telecommunications sector has its origin in the

[100] In the early 1990s, membership of CEPT was opened to new states in Central Europe. A full list of members and their respective years of joining the CEPT is available at http://www.cept.org/cept/about-cept/member-countries-and-year-of-admission

entry into force of the Single European Act (1986), with its objective to establish a single market by the end of 1992, although the telecommunications sector did not make the direct object of this original project. Of interest here, however, is the process by which the European Commission arrived to have a particular position in relation to the development of the telecommunications sector in the European Union, as understood in Art 129b and Art 129c of the Treaty of Maastricht (1992). There are three directions that informed the position and preference of the European Commission as a public actor with a specific agenda for market development and, implicitly, for the allocation of the radio resource in the 1990s. These three directions follow a particular logic for the development of the telecommunications sector based upon: a) a competitive market, b) an integrated market and c) a co-regulated market. Their origin and development formed the preference of the European Commission for an implicit redistribution of the radio resource for mobile communications services and, subsequently, informed the preference of the industry in response to the position of the Commission.

The preference for a more competitive market had its origin and development in the GATS negotiations starting in 1986 and concluding in 1997[101], which followed the progressive opening up of the telecommunications equipment market in the first round of the negotiations as well as the opening up of the telecommunications services market in the latter round of negotiations. As R. Niepold (2002), the former head of the Radio Spectrum Policy Unit of the European Commission noted, the liberalisation process in the European Community coincided with the international obligations of the GATS agreement, which set conditions between the trading partners regarding the relationship between the opening up of the mobile communications market and the allocation of the radio resource:

> "Since frequencies are an indispensible condition for access to a mobile market, disciplines have been laid down. GATS allows some freedom to allocate and assign frequencies subject to the obligation to do so in a reasonable, objective and impartial manner; restrictions may not be more burdensome than necessary to ensure the quality of the services and cannot be used as a disguised barrier to trade" (Niepold 2002: 132).

Thus, Niepold (2002) unveils the relationship between the project of liberalisation and harmonisation of telecommunications markets within the European Community and its

[101] These are the Uruguay Round (1986-1994) on the opening up of the equipment market in telecommunications and the post-Uruguay Round on the opening up of the services market in telecommunications (1994-1997).

wider context of trade liberalisation in the sector. In addition, Niepold stresses the relationship between a liberalised and harmonised market for mobile communications in the Community (EC 1987) and the implicit requirement for "the allocation and use of scarce resources […] in an objective, timely, transparent and non-discriminatory manner", as stipulated in the GATS Reference Paper on Basic Telecommunications (1996, Art 6). Against this background, the European Commission expressed a clear position that mobile communications markets offered an opportunity to further liberalisation in the sector:

> "Mobile communications thus is seen by a number of Member States as a major candidate for competitive supply. Exclusive provision of the main network infrastructure must not hinder the use of new technological opportunities by private systems" (EC 1987: 88).

This early position of the European Commission, formalised in the *Green Paper on the Development of the Common Market for Telecommunications Services and Equipment* (EC 1987), confirms that the entry of the European Commission in the regulation of telecommunications was incremental (Thatcher 2001), achieved through small steps that shifted, progressively, the line between traditional telecommunications services as "reserved services" and new communications services as "liberalised services", starting with the liberalisation of mobile and satellite networks, followed by cable networks and, ultimately, fixed telecommunications networks (Hancher and Larouche 2011: 746). This incremental position is confirmed by the first legislative package for the liberalisation of the telecommunications sector in the European Community – the Open Network Provision Directive 90/387/EEC and the Services Directive 90/388/EEC – which adopted competition in telecommunications networks and services other than "public voice telephony" (Art 1.2, Commission Directive 90/388/EEC). As Hacher and Larouche (2011) noted, "even if public voice telephony might sound restrictively defined, in fact more than 80 per cent of the sector as it existed at the time was left in the reserved services category" (Hacher and Larouche 2011: 746). This situation confirms that the European Commission responded to international pressures for institutional reform in the telecommunications sector (EC 1987: 155), but adopted an incremental approach that balanced the interests of telecommunications operators in new markets such as mobile communications with their interests in traditional markets such as fixed telecommunications.

This approach is furthered by the preference of the European Commission for a more integrated market in telecommunications across the European Community. Prior to the explicit formulation of its competences in telecommunications in the Maastricht Treaty (Art 129b-d), the European Commission established a functional relationship between the opening up of communications markets and their integration across Member States. The Green Paper (1987) voiced the position of the European Commission in relation to the development of open but integrated infrastructures for network industries, such as the Integrated Services Digital Networks[102] (ISDN):

> "By adapting the increasingly available digital narrowband infrastructure, ISDN will allow voice, data, text and simple video communication on the existing network. At the same time, ISDN allows the creation of a single market for advanced terminals, and lays the basis for the Community-wide introduction of new services. […] ISDN should become the Community's future-oriented open network infrastructure on which services can develop" (EC 1987: 117-118).

As Fuchs (1994) noted, the position of the European Commission for the development of integrated networks reconciled the gradual liberalisation of infrastructures and services with a guarantee of temporary survival of telecommunications monopolies in traditional fixed line services (Fuchs 1994: 183). This gave the European Commission a framework in which to maintain a balance between international commitments for the liberalisation of telecommunications markets and national commitments for the special, yet temporary, treatment of voice telephony services provided by monopoly operators. In addition, the European Commission promoted its preference for the development of integrated and interconnected telecommunications networks in European Research Programmes such as the Research into Advanced Communications in Europe (RACE) Programme (1988-1992).

The RACE Programme (1988-1992) is particularly relevant because it defined the political vision of the European Commission regarding the integration of mobile and fixed communications services in a single network deployed across the European Community:

> "The objectives of RACE are ambitious. It aims at the introduction of Integrated Broadband Communications (IBC) taking into account the

[102] The Council Recommendation on the Coordinated Introduction of the Integrated Services Digital Network (ISDN) in the European Community (86/659/EEC) had only been issued in December 1986, a few months prior to the publication of the Green Paper (EC 1987).

evolving ISDN and national infrastructure strategies, progressing to Community-wide services by 1995" (EC 1987: 116).

The vision of the European Commission for the Integrated Broadband Communications Network – also known as Broadband-ISDN or B-ISDN – followed the logic that new broadband networks would "be able to carry a broad range of services independent of network operation" (EC 1987: 33). The mobile component of this "monolithic" broadband network was the Universal Mobile Telecommunications Systems (UMTS), which would allow the deployment of mobile telephony and mobile data services on the network (Huber et al 2000: 130). However, as the former director of DG Information Society, J. da Silva[103] (2002) noted "such a new generation was seen as comprising not only novel radio techniques [i.e. not GSM], but also an open and flexible fixed infrastructure based on state-of-the-art technology" (2001: 116). Essentially, this vision for the mobile component of the B-ISDN network would replace existing mobile networks including the GSM digital network, which would upset newly established positions in this growing mobile communications market. However, in the view of the European Commission, this vision reconciled the interests of monopoly operators by maintaining their position in voice services with the interests of established manufacturers by sponsoring technology development at the pre-competitive phase in European Research Programmes, without upsetting international commitments to gradual liberalisation of networks and services.

Nevertheless, in the view of the European Commission, this balance of interests between operators and manufacturers could be maintained if both parties had an equal representation in decision-making processes regarding the choice of standards in future telecommunications networks. Historically, this balance could not be achieved in the CEPT, where telecommunications operators with administrative responsibilities (PTTs) were the only members given the vote on the harmonisation of telecommunications policy[104]. In addition, CEPT was not envisioned as a standardisation body, but as a policy harmonisation body for telecommunications operators across Europe (*Revisit Chapter 3.1*). This informed the decision of CEPT members to propose the creation of a

[103] J. da Silva is former director of DG INFSO.D "Converged Networks and Services" European Commission, EC Directorate General for the Information Society.

[104] As discussed in *Chapter 3*, it is important to stress that delegations of PTTs in CEPT would include both representatives of the operators with voting rights and representatives of their manufacturing partners (national based), with consultative rights.

standardisation body in telecommunications, which would provide an opportunity for both operators and manufacturers to continue and broaden the standardisation process commenced in GSM-CEPT. This standardisation body was the European Telecommunications Standards Institute (ETSI), set up in 1988, with representation in decision-making from all industry members based in CEPT Member States. In line with its vision, the European Commission supported the decision to transfer all standardisation responsibilities from CEPT to ETSI:

> "Jointly finance, the institute, based on a small core team of permanent staff and independently managed according to best business practice, should draw flexibly on experts from both the telecommunications administrations and industry, in order to substantially accelerate the elaboration of standards and technical specifications, indispensible for an open competitive market environment and the development of Europe-wide services" (EC 1987: 22).

The European Commission's support for the creation of ETSI is also a manifestation of the public actor's preference for co-regulation in the development of the telecommunications market. From this point of view, co-regulation did not only maintain the balance of interests between operators and manufacturers in support of the European Commission's vision for integrated networks of gradually liberalised services such as ISDN or B-ISDN. As Chalmers (2006) noted, co-regulation was instrumental to the realisation of collective problem-solving as a political good (2006: 21). In this context, co-regulation would facilitate the standardisation of new equipment and infrastructure in order to achieve the political goal of interoperable services deployed on integrated telecommunications networks across borders in the Union. For some, this position is an indication of the Commission's development as a corporate actor, with growing powers and resources, and with an interest to extend its prerogatives "by constructing Euro-centric networks"[105] (Schneider and Werle 1990). However, the view of the European Commission as a corporate actor, managing established networks of interests, does not seem to fully fit the account presented above (Fuchs 1995). Instead, in the early 1990s, the position of the European Commission is more likely to have been informed by the need to reconcile the interests of monopoly operators and the interests of manufacturers or, as Esser and Noppe (1996) described it, to "enable the muddling through by private actors" (1996: 548). The political vision of the European

[105] Note that this construction of Euro-centric networks refers to networks of interests rather than networks in telecommunications.

Commission for the creation of a monolithic infrastructure with flexible components and multiple services appeared to achieve this reconciliation of interests in light of the liberalisation of the sector.

Overall, the political vision of the European Commission is important to analyse for two reasons. First, and in contrast with the previous case study (revisit *Chapter 3.1.2*), the European Commission is a public actor with a clear position regarding the development of the mobile communications market, in the wider reform of the telecommunications sector, along the three lines identified above, i.e. a more competitive, integrated and co-regulated sector. Second, and again in contrast with the previous case study, the European Commission is a public actor with a clear preference for the development of a single, integrated infrastructure to support a variety of services across border, including mobile communications services replacing GSM. This position of the European Commission as a public actor with a clear preference for market growth based on innovation in cellular services, rather than replication of existing services, would have redistributive effects on mobile communications markets based on GSM and, subsequently, on positions of rivalry and excludability established on the radio resource that facilitated the growth of these markets. The next section discusses how the preference of the European Commission for the development of mobile communication services – as a flexible component to a single fixed infrastructure – conflicted with the position of private actors in digital cellular networks based on the GSM systems deployed in the 900 MHz band. The next section ends by showing that industry actors responded to the technology preference of the European Commission by strengthening private mechanisms of standards development in the newly created European Telecommunications Standards Institute (ETSI), which took over and formalised the standardisation process established, ad hoc, in GSM-CEPT.

4.1.3 The Initial Distribution of Private Interests and Private Resources

The response of the industry to the position of the European Commission reveals the overall strategies of private actors interested in the development of mobile communications services based on replication and evolution of existing systems (GSM), rather than based on innovation of new systems (UMTS as part of B-ISDN). In the early 1990s, this position was informed by considerations of return on investment in GSM networks as well as by the unprecedented growth potential of mobile communications markets based on the GSM system. These considerations aligned the strategies of both operators and manufacturers in favour of the replication of existing services in new frequency bands, coupled with the gradual evolution of the radio component of the GSM core network. In short, this gradual evolution would consolidate the market presence of both developers and operators deploying second generation mobile communications systems based on the configurations of rivalry and excludability set in the GSM MoU (1991).

For operators, the growth of the mobile communications market represented a clear incentive to improve their return on investment in GSM systems. This strategy was also justified by pressures of liberalisation, which was largely achieved through the remedy of a newcomer being awarded a second radio frequency license to balance the position of the incumbent (Larouche 2003: 11-13). However, the presence of new entrants in the mid 1990s did not reduce the overall market presence of mobile operator units of traditional fixed line providers[106]. On the one hand, the deployment of GSM systems in the harmonised 900 MHz band led to the gradual consolidation of the mobile operator units of traditional fixed line providers across the CEPT[107]. On the other hand, growing demand for mobile communications services translated into growing demand for space in the radio spectrum, which led to the licensing of new frequency bands for GSM systems in the 1,800 MHz band, turning GSM into a multiband standard. Overall, this consolidated the position of the initial operators of mobile communications services

[106] Although, by the mid 1990s, the administrative and operational responsibilities of PTTs were broken up to give rise to regulatory agencies, the operational branches of the PTTs continued to hold a dominant position in the market for both fixed and mobile communications.

[107] By the late 1990s, the most established pan-European service providers were Orange, O2, T-Mobile and Vodafone. *Orange* was owned by the Microtel Consortium and, in the early 1990s, was sold to Hutchinson Whampoa, to be later acquired by Mannesmann and sold to Telecom France in 2000. *O2* was owned by BT Cellnet and acquired by Telefonica in 2005. *T-Mobile* was owned by Deutsche Telekom and merged with France Telecom's *Orange* in 2010 to form EE in the United Kingdom. *Vodafone* was owned by Racal Electronics and renamed Vodafone Group when it acquired Mannesmann and Orange in 1999. It later divested and sold *Orange* to France Telecom in 2000.

across the CEPT, who collectively provided over 70% of these services in the mid 1990s[108] (Informa WCIS Database, Fuentelsaz et al 2008: 441-442).

For manufacturers, demand for mobile communications services based on the GSM system represented a clear incentive to improve their return on investment in the development of the system rather than to invest in the development of a new infrastructure along the vision of the European Commission. On the one hand, patent holders of GSM systems were drawing considerable benefit from the opening up of the GSM MoU (1991) to operators outside the CEPT. On the other hand, these developers were maintaining a dominant position across the CEPT, where GSM was exclusively deployed. According to Bekkers (2001), these manufacturers used their patent portfolios in GSM to apply a practice of "restrictive licensing", combining cross-licensing agreements among initial patent holders with a high license fee for non-patent holders, having the effect of slowing down market entry for non-European manufacturers and, essentially, reinforcing positions of rivalry and excludability in the market as well as in the radio resource (Bekkers 2001: 336).

Overall, both operators and manufacturers in the CEPT had strong incentives to grow their portfolios in GSM in order to recover their initial investment in developing and deploying the system, as well as to increase their profits in the young market for mobile communications. This is revealed by the strategies of established operators and manufacturers in European Research Programmes (RACE and ACTS) as well as in the newly created European Telecommunications Standards Institute (ETSI). These early strategies conflicted with the vision of the European Commission for an integrated infrastructure for all communications services and informed decisions about the technology for third generation mobile communications systems (UMTS) to be later deployed in the 1.9-2.1 GHz bands.

The RACE and ACTS European Research Programmes[109] followed the political vision of the European Commission for the creation of a single pan-European network entitled B-ISDN, which would "bring together the whole spectrum of the then conceivable telecommunications services", including mobile services (Fuchs 1994: 180). In the

108 At the time, pan-European service providers would hold several licenses across the CEPT market. For instance, Vodafone held seven licenses, whereas Orange and T-Mobile held two licenses each (WCIS Database, Accessed 15 December 2012).

109 Research into Advanced Communications in Europe (RACE); Advanced Telecommunications Technologies and Services (ACTS).

context of these research programmes, the Universal Mobile Telecommunications System (UMTS) was envisioned as the new mobile component of the B-ISDN network, with capacity to deliver low and medium speed data services in addition to mobile telephony. *Table 4.1* gives the participants in these development programmes, revealing that the majority of manufacturers with patent portfolios in GSM took part in RACE and ACTS projects.

Table 4.1 Selected Projects in Telecommunications and their Composition in European Framework Programmes, 1988-1998

European Framework Programme	Project	Participants
RACE I (1988-1992)	Mobile	Alcatel, Bosch, Ericsson, GEC-Marconi, Plessey
RACE II (1990-1994)	CODIT	Philips, Matra, CSELT, Italtel, Ericsson, Telia
	ATDMA	DeTeMobile (Deutsche Telekom), Alcatel, Fondazione Ugo Bordoni, Roke Manor Research Ltd
	MONET	Alcatel-SEL, Philips, Nokia, Ericsson, Telefonica, Post and Telecom of Finland, CNET, OTE, CSELT, Fondazione Ugo Bordoni, University Limerick, AT&T Network Systems, Royal PTT Nederland, University Twente, VTT Technical Research Centre Finland, Roke Manor Research
ACTS (1994-1998)	FRAMES	Siemens, Nokia, Ericsson, CSEM, CNET, Instituto Superior Tecnico, University of Kaiserslautern, Delft University of Technology, University of Oulu, The Royal Institute of Technology, Chalmers University of Technology, Roke Manor Research, Swiss Federal Institute of Technology, Integracion y Sistemas

Source: Based on EC (1989), EC (2000) and EC (2004b)

At first, this level of participation appears paradoxical, since each project focused on the development of new technologies to replace both the GSM radio access network and the GSM core network (da Silva 2002: 116). However, a closer analysis reveals the strategic behaviour of system developers in these programmes. On the one hand, developers used the research programmes to diversify their portfolios in radio access networks, by signing up to projects that researched technologies they did not hold a strong patent portfolio in. For instance, in RACE Phase II (1990-1994)[110], developers

[110] It should be noted that RACE Phase II (1990-1994) continued to focus on the development of radio access technologies to the B-ISDN core networks. As a result, it focused on testing the two competing technologies which made the debate in GSM-

holding extensive patent portfolios in TDMA radio access technology (e.g. Ericsson, Telia) took part in the CODIT Project, which tested CDMA-based radio technology. Similarly, developers holding extensive patent portfolios in CDMA radio access technology (e.g. Alcatel) took part in the ATDMA Project, which tested TDMA-based radio technology (*Table 4.1*). On the other hand, developers did not engage in registering any specific patents to the concluding FRAMES Project and, subsequently, the technology that made the object of this research remained in the portfolios of their initial owners once the project ended[111] (ACTS 2000). These findings are confirmed by studies looking at the behaviour of participants in early European Research Programmes, when industry members were not willing to produce collective results "beyond an increase in the competence of the participating unit" (Laredo 1998: 592). Thus, the assimilation of technology outputs resulting from European Research Programmes remained relatively low, unless otherwise desired by the private owners of these technologies.

These findings are also confirmed by the strategies of industry representatives, predominantly manufacturers, in the competing development group established in the European Telecommunications Standards Institute (ETSI). Following the creation of ETSI, the standardisation responsibilities for GSM systems were transferred from the CEPT to ETSI in 1988. The Group was renamed ETSI Special Mobile Group (ETSI SMG) and, at the beginning, it dealt exclusively with the standardisation of the GSM system. Most importantly, industry representatives in ETSI SMG invested in the development of an evolutionary path to providing data services using the GSM core network. This "evolutionary" path, known as GSM Phase 2 and Phase 2+, was a competitor to the "revolutionary" path proposed by the European Commission (Dupuis 2000). Instead of developing a new component to the B-ISDN network, ETSI SMG proposed to evolve the radio interface of the GSM system while maintaining its core network for delivering mobile communications. The situation in ETSI SMG explains why, in the early 1990s, manufacturers with portfolios in GSM were interested in

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CEPT regarding the radio interface, i.e. TDMA or CDMA, this time for the transfer of data services as well voice telephony.

[111] In contrast, all other ACTS Projects produced a total of 145 registered patents, see ACTS 2000.

developing evolved radio interfaces for its core network – such as GPRS or EDGE[112] – rather than investing in a new radio interface for a new core network, as envisioned in European Research Programmes (Dupuis 2000). This position reflected a clear preference for protecting investments in the GSM system as opposed to making new investments in the UMTS system as a mobile component of an integrated public network. For manufacturers, evolving GSM systems would protect the value of their patent portfolios. For operators, it would protect their investments in GSM networks, by making changes only to the periphery of these networks, in new terminals and base station software (Bekkers 2001: 344).

But, most importantly, evolving the GSM network would protect positions of rivalry and excludability established in the radio resource that facilitated the delivery of these mobile communication services. Investing in the vision of the European Commission for a new mobile component to a revolutionary public network would have had redistributive effects on these positions in the radio resource, a situation that was not desirable for either operators and manufacturers drawing increasing benefits from the deployment of GSM networks in Europe and worldwide. In comparison, by deploying existing systems in new radio frequency bands, these positions of rivalry and excludability would remain largely unchallenged. By the mid 1990s, these industry considerations had refocused the development work in European Research Programmes (ACTS) as well as the political vision of the European Commission. In the ACTS Research Programme (1994-1998), UMTS was envisioned in a more flexible manner, interworking with both GSM and ISDN networks, and relying on the evolution of second generation mobile networks as much as on the future fixed broadband network (da Silva 2002: 123). Similarly, the European Commission was increasingly supporting a flexible approach to UMTS as a third generation mobile communications systems that would evolve from the second generation GSM system:

> "Ultimately, personal communications services are likely to be carried most economically via a single integrated technology concept – the so-called UMTS (the Universal Mobile Telecommunications System). The

[112] Two evolutionary solutions to data services for GSM were reached in ETSI SMG in the mid 1990s: a) GPRS, a packet-switched service that would require changes to several GSM network components and a change in the business model of charging, from time-based charging to volume-based charging; c) EDGE, a faster packet switched service that would allow similar connectivity to GPRS (Bekkers 2001: 344, Selian 2003: 45).

> strong European position in digital mobile communications has made the Union a major actor in the work towards this future "third generation" system, building on the strengths of the current second generation digital mobile system" (EC 1994: 16).

By the mid 1990s, these changes in the vision for UMTS as third generation mobile communication services interworking with both second generation mobile communication systems (GSM) and the fixed public infrastructure (ISDN) led to a considerable duplication of research activity in European Research Programmes and in ETSI along parallel visions of the radio technology and network architecture for these future services[113] (Dupuis 2007). However, as indicated above, the strategies adopted by private actors, particularly manufacturers involved in this development work, differed between the European Research Programmes and ETSI. In short, developers used European Research Programmes to substantiate their portfolios with new technologies for UMTS, while using ETSI SMG to forward their system development work for GSM. At the same time, as Bekkers (2001) reveals, operators showed little interest in the development of UMTS, concerned mostly with increasing their GSM subscriber base (Bekkers 2001: 460). This picture reveals the centrality of manufacturers in the development of GSM and UMTS systems as well as the uncertainty regarding the configuration of UMTS as either an evolution from the GSM core network or a new radio component of the core public network. The remainder of this chapter follows the process by which manufacturers refocused the development and standardisation work on UMTS along an evolution of the GSM core network, by setting new operational rules for system development in the 1.9-2.1 GHz band in ETSI SMG. Before exploring this relationship between the development of the UMTS system and the configuration of rights of use in the 1.9-2.1 GHz bands, the next section discusses how international rights of access in the 1.9-2.1 GHz bands came to be interpreted in relation with a third generation mobile communication system with a mobile and fixed layer, resembling the vision of the UMTS taking shape in Europe (Callendar 1994).

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[113] Confirming these parallel visions, P. Dupuis (2007) noted that "it is not exaggerated to say that, around 1990, there was a certain competition between the GSM group and RACE 1043" (Dupuis 2007). Race 1043 was the research project aimed at the introduction of B-ISDN.

4.2 The Process of Private Rule-Making in the 1.9-2.1 GHz Band

This section follows the process of negotiating operational and collective choice rules for the deployment of third generation mobile communications based on UMTS as an evolved system specification from GSM, as preferred by a number of key manufacturers holding essential intellectual property in these systems. The section reveals that this situation of increased heterogeneity in the distribution of technology capabilities among a few industry actors, holding considerable essential intellectual property, permitted the creation of new rules of management and new rules of exclusion for systems to be deployed in the 1.9-2.1 GHz frequency bands. This situation stands in contrast with the previous case study where industry actors were not willing to invest in decision-making procedures other than those already established in CEPT. In contrast, decision rules and procedures in ETSI were negotiated and renegotiated in order to reflect the large manufacturing base represented in this interest association, as well as their technology preferences regarding the exclusion, rather than inclusion, of competing systems. Although these collective choice arrangements allowed industry actors to adopt a set of operational rules for systems to be deployed in the 1.9-2.1 GHz band, they did not ensure internal monitoring of technology preferences by different manufacturing groups and they did not ensure the equal representation of operators in the standards development process that defined operational rules of access and use onto the 1.9-2.1 GHz bands. As a result, operational arrangements for UMTS were contested both from within by manufacturers and operators from the CEPT as well as from without by manufacturers from other radio regions, particularly the United States.

4.2.1 Negotiating Rules of Access

In 1992, the World Administrative Radio Conference of the ITU (WARC 92) identified a block of frequencies between 1,885-2,025 MHz and 2,110-2,200 MHz (i.e. 1.9-2.1 GHz) for use by Future Public Land Mobile Systems (FPLMTS). This allocation was surprising in both substance and procedure. On the one hand, it allocated frequencies in the 1.9-2.1 GHz bands to mobile communications services of a particular technology specification (FPLMTS), which broke with the tradition of allocating international frequency bands to broad families of services. On the other hand, it made this allocation in a footnote of the WARC 92 Radio Regulations, which broke with the tradition of stipulating it in the Table of Allocations or in a Resolution. The footnote read:

> "The frequency bands 1,885-2,025 MHz and 2,110-2,200 MHz are intended for use, on a worldwide basis, by administrations [governments] wishing to implement the future public land mobile systems (FPLMTS). Such use does not preclude the use of these bands by other services to which these bands are allocated" (ITU 1992: ADD 746A).

In short, this footnote proposed limiting access onto the 1.9-2.1 GHz frequency bands to providers of terrestrial mobile communications[114] that met specifications for future public land mobile systems (FPLMTS), which at the time were developed in the international standardisation body of the ITU (CCIR[115]) with considerable input from CEPT members (Adams and Frank 1992: 45). The flexible allocation provided in the footnote – i.e. "such use does not preclude the use of these bands by other services" – responded to the position of the Federal Communications Commission (FCC) of the United States, who opposed the position of CEPT members to make additional allocations for mobile communications services at that time. The remained of this section follows how the vision for third generation communications networks put forward in Europe came to inform the configuration for future public land mobile systems (FPLMTS) at international level, how it came to be opposed by the FCC and, ultimately, how it came to define flexible rules of access onto the global 1.9-2.1 GHz band, which contributed to increased contestation of technical specifications for the use of this band at international level.

The project for Future Public Land Mobile Systems (FPLMTS) had its origin in the work of the International Radio Consultative Committee (CCIR) of the International Telecommunications Union (ITU). The project started in 1985 and was developed by Task Group 8/1 of the CCIR with the view to make recommendations on spectrum requirements for future mobile communications at WARC 92. Overall, it is recognised that early work in Task Group 8/1 reflected uncertainty about technology capabilities for future mobile systems as well as uncertainty about harmonising such systems at international level (Bekkers 2001: 481, Searle 1991: 1788). This situation translated into

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[114] Within this range, bands 1980-2010 MHz and 2170-2200 MHz were identified for the satellite component of these mobile communications services. However, for reasons of brevity, this chapter will refer to those frequencies in the 1.9-2.1GHz band designated exclusively for terrestrial, rather than satellite, communications services.

[115] The International Radio Consultative Committee of the International Telecommunications Union, currently ITU-R.

uncertainty about radio spectrum requirements for future mobile communication systems in international allocations. In preparation for WARC 92, CEPT provided Task Group 8/1 with its own considerations for spectrum requirements based upon the vision of future public land mobile systems “as a third generation personal communication system [UMTS], in the context of second generation mobile and cordless systems” (Searle 1991: 1787, text in parenthesis added). In preparation for WARC 92, the CEPT concluded a requirement of “a minimum bandwidth of approximately 230 MHz” for a vision of future public land mobile systems that combined the vision of RACE (1990-1994) and ETSI for UMTS as a third generation mobile communication system, which would be deployed in the early 2000s, allowing for the gradual phasing out of GSM networks. For this gradual process to take place, without upsetting radio allocations for GSM networks in Europe, new frequency bands were proposed for UMTS as FPLMTS around the 2 GHz frequency band. This position was embraced by the Task Group 8/1 in CCIR Recommendation 687, which identified a bandwidth requirement of 230 MHz for FPLMTS. As Searle (1991) noted, this represented a departure from the established practice at ITU World Radio Conferences:

> “The identification of FPLMTS as a specific WARC 92 agenda item is somewhat unusual in that it seeks to define spectrum use at a more detailed level than the generic service e.g. Mobile, Fixed, Fixed Satellite” (Searle 1991: 1790).

The Federal Communications Commission (FCC) of the United States contested this proposal at WARC 92. There were two interdependent reasons for the position of the FCC. First, it opposed allocating additional radio resource to terrestrial mobile communication systems that, in the view of the FCC, could have been flexibly allocated by operators in the 900 MHz or 1,800 MHz bands reserved for technology neutral mobile communications services in the US. This position of the FCC to allow operators to upgrade to third generation services at their own will came in stark contradiction with the position of CEPT Members, which conditioned access onto the 900 MHz band and 1,800 MHz band to second generation GSM systems (revisit *Chapter 3*). Thus, the FCC found that its regulatory approach to bands previously designated for mobile communications systems gave enough flexibility to phase out services for next generation systems without the requirement for additional bands. Instead, the FCC was more interested in the deployment of satellite mobile communications in the 2 GHz band. Second, the FCC opposed conditioning access to the 1.9-2.1 GHz bands to terrestrial mobile communications services whose technology specifications were being defined by European interests:

> "FPLMTS refers to a concept being developed in the CCIR primarily by European radiocommunications interests for delivering mobile telecommunications services in the 21st century. […] The European view FPLMTS as the successor to the Global System for Mobile Communications (GSM) – a pan-European digital cellular system that is currently being deployed across Europe. […] The United States made no specific allocation proposal for FPLMTS, citing the extensive existing allocations available for mobile services, uncertainty over just what FPLMTS is, and the possibility of making FPLMTS-like services available through standards-setting and common (global) interoperability requirements rather than through a new frequency allocation" (US Congress 1993: 78).

This excerpt reveals the basis for the compromise reached at WARC 92. On the one hand, rules of access onto the 1.9-2.1 MHz bands were not defined in relation to FPLMTS systems in the Table of Frequency Allocations of the Radio Regulations. On the other hand, the footnote to the Table of Allocations gave a green light to European administrations to implement FPLMTS if they so wished, as long as "such use does not preclude the use of these bands by other services to which these bands are allocated [on a primary basis]" (ITU 1992: ADD 746A). In addition, Resolution 212 of WARC 92 regarding the "Implementation of Future Public Land Mobile Telecommunications Systems" noted that CCIR was invited to "continue its studies with a view to developing suitable and acceptable technical characteristics for FPLMTS that will facilitate worldwide use and roaming […]" (ITU 1992: RES212). This recommendation reflected the position of the United States regarding the "uncertainty over just what FPLMTS is" (US Congress 1993: 78) and pointed at the lack of consensus for the vision of UMTS as third generation mobile communication systems put forwards by European Research Programmes and ETSI, as discussed in the previous section. In this light, the remainder of this chapter focuses on the process by which manufacturers took an active role in defining the standard for third generation mobile communications services away from the revolutionary conception envisioned by the European Commission and toward the evolutionary conception based on the core GSM network, designed to replicate position of rivalry and excludability already achieved in frequency bands where GSM networks were deployed. The development of the standard was achieved away from the venue already established by the European Commission, such as the European Research Programmes, and into the private venue of the European Telecommunications Standards

Institute (ETSI), set up with particularistic rules of representation and decision-making that favoured system developers with considerable operations across the CEPT.

4.2.2 Negotiating Rules of Management and Exclusion

The uncertainty regarding the basic technology specifications and the radio resource requirements for the UMTS system were negotiated and resolved in ETSI SMG from 1996 to 1998. This situation followed from considerable changes in the decision-making rules, the voting procedures and the intellectual property policy of ETSI in the first half of the 1990s. As a newly created not-for-profit standardisation organisation, with a more diversified membership basis than the CEPT but with the same geographic reach, ETSI spent its first years creating rules regarding the procedures for defining telecommunications standards. This section examines the steps adopted in ETSI and ETSI SMG to define collective choice rules of management (decision-making, voting) and collective choice rules of exclusion (membership, intellectual property policy) in order to maintain positions of rivalry and excludability established in the mobile communications market following the deployment of GSM networks. The section concludes that these rules facilitated the re-definition of UMTS as third generation mobile communication services deployed on the same network infrastructure as GSM, offering – at least in the initial stage – a duplication of services with GSM Phase 2+ and, subsequently, leading to an overestimated allocation of radio frequencies for these services in the 1.9-2.1 GHz bands across Europe. The redefinition of UMTS as a third generation mobile communication service deployed on the core GSM network was proposed and supported by manufacturers represented in ETSI SMG.

As discussed above, ETSI was established in March 1988 in order to further the development of European standards in telecommunications and to ensure that both operators and developers are equally represented in decision-making during the standardisation process (revisit *Section 4.1.2*). However, from the start, rules of membership and participation in ETSI set it apart from other international standardisation bodies (Besen 1990: 522). There are three overarching policies that define the boundaries of collective choice rules in the specification of telecommunications standards in ETSI and, as a result, have a direct impact on configurations of rivalry and excludability in the radio resource that deploys these systems. These overarching policies with direct impact on collective choice rules of management and exclusion in radio systems are: a) the rules of membership; b) the rules of decision-making; and c) the rules defining the relationship between the intellectual property of members and the standards produced by ETSI. As it will be discussed below, it was only after these collective rules of management and exclusion were defined that system developers agreed to consolidate and fast-forward the standardisation of UMTS in ETSI SMG.

First, rules of membership in ETSI are defined in relation with two principles of inclusion-exclusion. On the one hand, membership in ETSI is open to wider categories of interests than the CEPT, including telecommunications administrations, network operators, manufacturers, research bodies and user organisations (*Table 4.2*).

Table 4.2 ETSI Membership by Category (5), 1992 and 1997

Membership Category	**% Total Full Members 1992**	**% Total Full Members 1997**
Manufacturers	61.5%	53%
Public network operators	14%	16%
Administrations, national standards bodies, other administrative bodies	10%	10%
User organisations	8%	6%
Service providers, consultancy partners, research bodies	6.5%	15%
Total	309 (100%)	457 (100%)

Source: Based on Bekkers (2001), Fuchs (1994), Hillebrand (2002)

On the other hand, full membership with voting rights in ETSI is restricted to CEPT Members[116], applying the same principles of exclusion based on geographic representation as in the previous case study discussed in this thesis. *Table 4.2* provides figures for the composition of ETSI by membership category in 1992 and 1997. The figures show that manufacturers based in CEPT had the consistently widest representation in ETSI, at over 50% of all members throughout the 1990s. Interestingly,

[116] Besen (1990) noted that, in the early 1990s, ETSI members were drawn from 21 countries represented in CEPT: "In addition to members from countries that belong to the EC, there are members from Austrial, Cyprus, Finland, Iceland, Malta, Norway, Sweden, Swithzerland and Turkey" (Besen 1990: 522).

public network operators maintained representation around 15% of all members in ETSI in the 1990s, although the process of liberalising network services was underway across the CEPT. These figures speak for the relative lack of participation of mobile operators in the standardisation process in ETSI SMG, which can be explained by their more active participation in the GSM MoU - the operators' association concerned with the deployment, extension and harmonisation of GSM networks.

Second, rules of decision-making concern both the voting procedure and the overall organisation of ETSI. The rules of decision-making in ETSI, as well as their reform in the mid 1990s, are essential in defining collective choice rights of management in mobile communication systems and in the radio resource used for their deployment. As Besen (1990) noted, one of the decision rules that sets ETSI apart from other international standardisation associations is its use of weighted voting rather than consensus voting (Besen 1990: 523). This meant that telecommunications standards could be adopted if they received a 71% weighted majority (Besen 1990: 523, Bekkers 2001: 152). This measure is thought to have been created in order to respond to deadlock situations similar to the one described in the previous case study, when consensus voting on technical specifications for the GSM standard blocked its initial adoption in GSM-CEPT as a result of the opposing vote of the French and German operators (revisit *Chapter 3.2*). In addition, this measure was adopted in order to provide incentives for system developers to forward the process of standardisation at the lowest level of Technical Committees and Project Teams, which were operating by informal consensus and would, subsequently, avoid deadlock by putting standards through a majority vote in the Technical Assembly.

An equally important consideration of the voting procedure is the use of turnover and/or GDP weighted voting[117], which has the effect of differentiating among voting members, giving more weight to insiders with the largest contribution in telecommunications markets across the CEPT. This form of market proportionality in the weight of the vote in ETSI sits in stark contrast with the one-member-one-vote principle in the standardisation process established in other standardisation associations. In short, this

[117] As Bekkers (2001) explains, depending on the object of the vote, voting is cast either by national delegations or by individual members (Bekkers 2001: 153). On most issues, including ETSI standards, individual voting – rather than national voting – applies. Individual voting is weighted on the annual turnover of the member and, in the case of administrations, on their GDP.

method gives considerable weight to the market interests of companies with the largest turnover in the telecommunications sector. And, combined with the representation of the different interests, this method has been regarded as favouring incumbents over new entrants as well as, in case of an alignment between the technology preference of operators and manufacturers with the highest turnover, a bypass of a minority vote on the configuration of a given standard in ETSI[118] (Bekkers 2001, Besen 1990, Cowhey et al 2008). As the first Director of ETSI, D. Gagliardi (1988) noted, the structure of weighted majority voting, combined with the proportion of interests represented in ETSI, meant that technology preferences were no longer defined along country lines but along membership category lines, giving considerable weight to the vote of manufacturers with the highest turnover (Gagliardi qtd in Freeman 1988: 91, Gagliardi qtd in Dodsowrth 1988). Overall, the combined effect of weighted majority voting and the representation of telecommunications actors gave considerable weight to the economic interests of established developers in CEPT and facilitated changes to the Intellectual Property Rights Policy in ETSI (1994) as well as its organisational reform in 1996. These two issues are brought to closer analysis because they inform the definition of rights of exclusion and rights of access to the 1.9-2.1 GHz bands via the negotiation of technology specifications of the UMTS system to be deployed in these bands.

The relationship between the intellectual property of members and the specification of standards with essential configurations based on their intellectual property can have the effect of destabilising positions of rivalry established in communication markets. The previous chapter provides an example of this case, when rules for patent exchanges in the GSM MoU (1987) had to be altered in order to reflect the position of manufacturers, such as Motorola, who at an initial stage refused to make essential patents available to members of the GSM MoU on fair, reasonable and non-discriminatory terms (revisit *Chapter 3.3*). M. Johnson, Director of the ITU Telecommunications Standardisation

[118] Similarly, the ETSI budget was drawn from the contributions of its individual members and was also tied to their market revenues. As it is expected, the costs of standards-making were covered by individual members based on their turnover, while optional standards making was covered solely by the specific members willing to produce the standard (Gagliardi qtd in Freeman 1988: 31). European Standards (for EC members) fall within this latter category and, as a result, the European Commission can sponsor some of the standardisation activity for these standards. Note that European Standards (EN series) differ from the general ETSI Standards (ES series).

Bureau, explains the issue at stake in the relationship between intellectual property and standardisation in the electronic communications sector:

> "IPR holders need an assurance of reasonable compensation for the adoption of their IPR-protected innovations to motivate their contribution of such innovations to standards development processes. Potential standards implementers similarly require the security of a reasonable IPR licensing fee to motivate their conformance with standards" (Johnson 2014: 3).

These two facets were at the core of negotiations regarding the IPR Policy on ETSI in the early 1990s. In fact, the transfer of standardisation responsibilities from GSM-CEPT to ETSI SMG also transferred the problem of disclosure and availability of essential patents confronted by members of GSM-CEPT in the early 1990s. The main negotiation concerned the establishment of an IPR pool or an IPR Policy with a disclosure/withholding period prior to the adoption of a standard – a proposal supported by network operators – and the establishment of an IPR Policy based on fair, reasonable and non-discriminatory terms (FRAND) – a proposal supported by system developers and similar to most standardisation associations (Bekkers and West 2009, Iversen 1999). Between 1993 and 1994, ETSI proposed, voted and passed two IPR Policies. The first IPR Policy (1993) followed the proposal backed by network operators for FRAND licensing with a disclosure/withdrawal period. The second and final IPR Policy (1994) followed the proposal backed by manufacturers for FRAND licensing with the elimination of a disclosure period. The voting procedure and composition of ETSI facilitated this swift change and the final IPR Policy (1994) was adopted with 87.2% majority vote in individual weighted voting and 90.3% in national weighted voting (Communications Standards News 1995). Most importantly, the IPR Policy (1994) formalised situations when ETSI members can choose not to license an IPR internally but to license it externally, with the effect of blocking the development of the standard, leading to a reconfiguring of position of rivalry and excludability in the association.

Similarly, the voting procedure and composition of ETSI facilitated its organisational reform in the mid 1990s. Upon its creation, ETSI followed an organisational structure comprising a General Assembly, a Technical Assembly, Technical Committees and Project Team. As Bekkers (2001) and Besen (1990) show, the Technical Assembly represented the highest authority for the production and approval of standards, which were developed in Project Teams and Technical Committees. However, by the mid 1990s, standardisation in ETSI was considered costly and lengthy (Communications

Daily 1995). In the early 1990s, communication between project teams was considered problematic even inside ETSI SMG. For instance, P. Dupuis recalls that, although ETSI SMG had a subcommittee charged with the development of UMTS following the integrated vision put forward in European Research Programmes, it had limited scope for how to implement this vision due to reduced communication with the subcommittees concerned with the development and implementation of GSM and evolutionary GSM Phase 2+ networks (Dupuis 2002c: 181).

Between 1995 and 1996, ETSI undergoes a major reform that removes the Technical Assembly – the ultimate decision-making forum on draft standards – from its organisational structure. The reform was introduced in order to reflect a paradigm shift in ETSI towards market-driven standardisation, based on existing demand for mobile communications such as GSM. In short, this paradigm shift to market-driven standardisation removed the vision of UMTS as a revolutionary mobile communication component of the B-ISDN network and brought it closer to the standardisation of evolutionary services of the GSM core network (Dupuis 2000). In addition, by removing the authority of the Technical Assembly from standardisation decisions, Technical Committees such as ETSI SMG would gain autonomous status to adopt draft standards prior to a vote in the General Assembly. As the former Chairman of ETSI SMG, F. Hillebrand (2002) noted:

> "A far reaching autonomy was agreed for Technical Committees on all technical matters. The concept of ETSI Partnership Project was created. This was an activity when there is a need to co-operate with an external body and where such co-operation cannot be accommodated within an ETSI Project or Technical Committee. This model had been designed within ETSI with the GSM and UMTS work in mind" (Hillebrand 2002: 95-96).

This model of standardisation was fundamentally different from the one established in GSM-CEPT. First, it departed from the equal representation of the technology preference of each member in the development of a communications system – as in the case of GSM for the 900 MHz band – to a majority representation of the technology preference of each member. Second, and of most importance, it departed from commercial considerations of frequency harmonisation at regional level to commercial considerations of market efficiency and market standardisation at global level. This shift to market-driven standardisation informed considerations to maintain the vision of UMTS as a voice and added data service, similar to the revolutionary conception of the system, and to link it to the GSM core network, similar to the evolutionary conception of the system. The effect was that UMTS would require a similar radio resource allocation to the one put forward by CEPT at the international conference WARC 92 – i.e. 1.9-2.1 GHz – in order to deliver services similar to the evolved GSM systems deployed in the 900 MHz and 1,800 MHz bands.

4.2.3 Negotiating Rules of Use

In 1996, a group of experts, headed by Alcatel and comprising the main telecommunications manufacturers in Europe[119], produced the Global Multimedia Mobility Report concluding that UMTS would require a new access network, a radio interface and new terminals and could be associated in a flexible manner to any core networks including GSM, ISDN, B-ISDN (TDoc SMG 194/96, Dupuis 2002c: 183, Samukic 1998: 1101). This report put forward a flexible approach that would gain the support of the UMTS Task Force, the advisory group proposed by the European Commission to deliver a common strategy for third generation mobile systems. F. Hillebrand[120], the Chairman of ETSI SMG at the time, noted that the report produced a controversial debate in ETSI about how best to reorganise UMTS work and what Technical Committee this work should go to, which resulted in little consensus within the Assembly (Hillebrand 2002: 185). However, the Report received a proposal from ETSI SMG, which endorsed the recommendations and offered to take responsibility for specifying the UMTS radio access network, the interface and the added multimedia services (SMG#19 Plenary, Hillebrand 2002: 185, Huber et al 2000: 130).

The position adopted by ETSI SMG in relation with the recommendations of the Global Multimedia Mobility Report was the crucial step towards the reconfiguration of UMTS as an evolutionary radio access network based on core network of GSM. There are two main reasons why this is important for the reconfiguration of UMTS as an evolutionary system. First, ETSI SMG had its roots in the former GSM-CEPT group, which, throughout the early stages of ETSI, maintained a degree of autonomy, compared with other Technical Committees, by keeping an exclusive focus on the development of a single standard – GSM. Second, ETSI SMG was already working on added services to

[119] A full list of participants is available in ETSI TDOC SMG 194/96, Annex 3.
[120] F. Hillebrand has been actively involved in the standardisation process for both GSM and UMTS.

GSM networks, such as GPRS and EDGE, as part of the GSM Phase 2+ programme. In this context, UMTS could be developed in a similar fashion to GPRS and EDGE, by developing a new radio access network to be linked to the existing GSM core network. This scenario was perceived as offering the middle ground for both manufacturers and operators with interests in GSM. For manufacturers, it would reduce the costs of developing new system that would allow for the integration of mobile services into the public network, as proposed by the European Commission. For operators, it would reduce the costs of investing in new core networks too soon after the considerable investments achieved for GSM.

Soon after the restructuring of the decision-making process in ETSI, SMG signed a cooperation agreement with the Japanese Association of Radio Industries and Businesses (ARIB) and the American National Standards Institute (ANSI T1P1). This agreement followed from the decision to align ETSI with partner SDOs for the creation of market-based global standards. Both organisations had strong ties with GSM system providers and operators, which was perceived as strengthening external support for the evolutionary vision of UMTS. Whereas ANSI T1P1 established ties with manufacturers to deploy GSM networks in parts of the technology-neutral 1,900MHz band designated for Personal Communication Services (PCSs) in the United States, the Telecommunication Technology Committee – the standardisation organisation in Japan – nominated ARIB to study third generation mobile services (Bekkers 2001: 328, 463). The European-Japanese cooperation agreement is significant for the future development of UMTS as an evolutionary standard.

In 1997, NTT DoCoMo, the privatised Japanese telecommunications incumbent, opened bids for third generation networks based on W-CDMA radio technology[121], which were won by Ericsson for the network infrastructure and by Nokia for terminals deployment (Bekkers 2001: 464, Clarke and Lammers 1997). As indicated in the previous section, both Ericsson and Nokia were involved in the RACE Phase II and ACTS research programmes and were focused on developing and testing CDMA-based radio access technologies to diversify their companies' portfolios, which at the time were largely TDMA-based – i.e. the radio access method for second generation GSM networks (revisit *Table 4.1*). Essentially, winning these bids allowed Ericsson and Nokia to perform test trials as well as to deploy this new technology for next generation

[121] This radio access technology stands for wideband code division multiple access.

mobile services outside the policy venues established by the European Commission in the RACE Programmes and thus, without the requirement to register patents in the programmes. In addition, both Ericsson and Nokia supported W-CDMA as the global alternative to cdma2000, a competing third generation standard, which was being developed in North America by a consortium led by Lucent, Motorola, Nortel and Qualcomm (Bekkers 2001: 467). These circumstances gave Ericsson representatives momentum to propose a cooperation agreement between ETSI SMG, ARIB and ANSI T1P1 in order to support the evolutionary pathway to UMTS based on W-CDMA.

The proposal was voted at the SMG#21 Plenary in February 1997 (Hillebrand 2002: 196). Soon after, Ericsson, Nokia, Alcatel and Siemens expressed their joint commitment to deploy future third generation mobile systems – UMTS – based on an evolution pathway from the GSM core network in the 1.9 -2.1 GHz band (BusinessWire 1997, McIvor 1997). Thus, the position of the four largest telecommunications equipment suppliers in Europe, coupled with the international backing of external industry associations, speeded the standardisation process for third generation mobile systems in ETSI. In addition, the key position of the four largest telecommunications equipment suppliers in ETSI SMG gave weight to the conception of UMTS as an evolutionary path from the GSM core network as well as its backward compatibility with the GSM standard.

The position of these four manufacturers in ETSI SMG was very important to promoting the technical specifications of the third generation system to be deployed in the 1.9-2.1 GHz band as evolving from GSM and, subsequently, to maintain the position of rivalry and excludability already achieved by the GSM system in other bands such as the 900 MHz band. In addition, the autonomy of ETSI SMG with regard to the standardisation process allowed the transition from the revolutionary to the evolutionary vision of UMTS to be easily introduced on the agenda of the group (Dupuis 2000). Thus, in the span of just over a year – i.e. from 1997 when the four manufacturers expressed their joint commitment to support UMTS as evolving from GSM to 1998 when competing technology specifications for UMTS were put through the vote in ETSI SMG – industry actors were able to completely change the vision of UMTS.

However, although majority voting rules were in place and decision making in ETSI SMG was autonomous from the rest of the organisation, the industry actors sharing the core technology capabilities – i.e. Ericsson, Nokia, Siemens, Alcatel, Motorola – could not agree on a single radio access technology for UMTS to be integrated in the evolved GSM core network. As a result, in June 1997, at the ETSI SMG#22 Plenary, group members agreed to bring forward five competing technology solutions[122] based on the validation tests that took place in the FRAMES Project[123] (revisit *Table 4.1)*. However, because most of the manufacturers represented in ETSI SMG had developed radio access technologies for third generation systems outside the FRAMES Project and prior to the decision by ETSI SMG to evolve UMTS from GSM, there was limited internal monitoring of the patents held by the participating actors as well as limited knowledge of their preferences. This situation determined F. Hillbrand, the Chairman of ETSI SMG, to propose more flexible voting arrangements in the Committee, by which two rounds of votes were introduced – an "indicative round" and a "decisive round" (SMG TDoc 858/97, Hillebrand 2002: 199). This voting procedure, designed to steer the decision-making rules to flexible consensus between the two voting rounds, led to the elimination of three of the five technology proposals but maintained the split between equipment manufacturers with the largest technology capabilities in Europe (*Table 4.3*).

Table 4.3 Main UMTS Radio Access Interface Alternatives (UTRA), Proponents and % Votes in ETSI SMG

Proposal	***Main Proponents***	***% Votes SMG#24***	***% Votes SMG24#bis***
Alpha (WCDMA)	Ericsson, Nokia, NEC, NTT DoCoMo, Telecom Italia, Telecom Finland	58%	61%
Delta (TD-CDMA)	Siemens, Alcatel, Bosch, Motorola, Italtel, Nortel	41.55%	38.7%

Source: ETSI SMG Report of Meetings SMG#24 (1997) and SMG#24bis (1998)

Following this procedural change, the first "indicative" vote in ETSI SMG#24 revealed that no technology option had reached the 71% majority vote needed under majority rules. Subsequently, a repeat vote was scheduled for SMG#24bis in January 1998. Thus, between the votes, industry representatives were given an opportunity to renegotiate

[122] The five concepts were registered as follows, with the proposed technologies in parenthesis: Alpha (WCDMA – Wideband Code Division Multiple Access), Beta (OFDMA – Orthogonal Frequency Division), Gamma (WTDMA – Wideband Time Division), Delta (Wideband TD/CDMA), Epsilon (ODMA – Opportunity Driven).

[123] As indicated in Section 4.2.3 of this chapter, industry actors chose not to register patents for UMTS in the FRAMES Project and, as a result, all these technologies remained part of individual portfolios and proprietary.

technology preferences with fellow manufacturers as well as with operators of mobile communications networks. For the latter group – i.e. mobile operators – the two technologies offered different incentives. On the one hand, promoters of TD-CDMA were arguing that their solution offered the smoothest transition from the GSM air interface, which was TDMA-based, and would require the least changes in software and infrastructure. In fact, the main promoters of TD-CDMA had proposed this air interface to the GSM MoU Association as the most acceptable standard for operators around the world, due to its protection of previous infrastructure investments in second generation networks (Meredith 1997). On the other hand, promoters of W-CDMA were arguing that their technological solution would offer the most competitive position in the global market for third generation mobile services and, although more expensive to implement, would constitute a long term competitor to cdma2000 – the third generation radio standard proposed by the North American consortium led by Qualcomm, Motorola, Nortel and Lucent (ETSI SMG(97)5, Part B). These considerations split the votes of operators as well as manufacturers that had not been directly involved in the development of one of the two proposals.

In addition, although the main service operators with deployed GSM networks in the 900 and 1,800 MHz bands were present at the meetings, they had little representation in the development process of these systems – unlike the development pairs established for GSM – and did not take part in system trials – unlike the Paris Trials for GSM (1986) – where the quality, spectrum efficiency and cost efficiency of these network were tested. This explains why, at the vote in ETSI SMG#24 Plenary, the Chairman of the Committee, F. Hillebrand, noted:

> "It is remarkable that, except for France Telecom, no GSM operator presented a contribution or declared a position at SMG#24. […] No technical, operational or planning aspects were addressed by operators other than France Telecom. This was a complete change compared to the situation in the GSM radio decision in 1987" (Hillebrand 2002: 205).

The "decisive" vote, held in SMG#24bis led, once again, to no majority option for the UMTS air interface (*Table 4.3*). Subsequently, Ericsson, Nokia and Siemens brokered a deal outside the formal procedures established in ETSI SMG (Hillebrand 2002: 203), so that the UMTS radio access interface would contain both technology solutions, harmonised at the interface level as follows (ETSI SMG(81)1 Annex 5):

- W-CDMA would be used in paired spectrum bands for UMTS (1,920-1,980MHz in the uplink, from terminals to base station; 2,110-2,170 in the downlink, from base station to terminals)

- TD-CDMA would be used in unpaired spectrum bands for UMTS

In order to secure the agreement, and benefiting from its considerable autonomy, ETSI SMG did not hold another vote in the General Assembly. F. Hillebrand, the Committee Chairman, noted that this decision was taken on grounds that ETSI SMG had a considerable industry representation:

> "[I]n terms of the number of delegates, but also the number of weighted votes represented, this [the SMG#24bis Plenary] was equal to a well attended General Assembly of ETSI" (Hillebrand 2002: 202)

Thus, the autonomous status of ETSI SMG facilitated the establishment of flexible decision-making rules concerning the technologies that would frame rules of access and rules of use in the 1.9-2.1 GHz band for the deployment of UMTS as based on an evolved GSM core network. However, the limited rules for monitoring internal technology capabilities and technology preferences among manufacturers, combined with the limited participation of service operators in the early development stages of these technology systems or in system trials, exposed the weakness of collective choice rules for spectrum management in ETSI SMG.

4.3 The Impact of Private Association on the Choice of Property System

This section shows that the organisation of industry actors in ETSI SMG differed from that in GSM-CEPT, as presented in the previous case study. The main element of difference stems from the larger number of participants in ETSI SMG, combined with their more diversified technology capabilities. However, because both operators and manufacturers had similar economic interests to replicate operational rules for the 900 MHz band in the 1.9-2.1 GHz bands, they were willing to invest in coordinating standardisation activity for third generation systems in ETSI. In particular, manufacturers with interests in maintaining their positions of rivalry and excludability derived from GSM were active in devising decision-making procedures to support the quicker adoption of standards in ETSI. These decision rules allowed established manufacturers, such as Ericsson, Siemens, Nokia and Alcatel, to gain support from service operators to change the development direction preferred, initially, by the public actor for “revolutionary” third generation systems based on integrated public networks, to “evolutionary” third generation system based on evolved GSM networks (*Table 4.4*).

Table 4.4 "Revolutionary" versus "Evolutionary" Conceptions of UMTS

	Pre 1998	***Post 1998***
Access Network	UMTS	UMTS
Interface	Multiple	WCDMA
Core network	(B)-ISDN	GSM
Architecture	Single network	Horizontal network
Frequency Allocations	2GHz band	2GHz band

Source: Based on Dupuis (2000), Hillebrand (2002) and Huber et al (2000)

Whereas the shift from “revolutionary” to “evolutionary” systems clarified the main rules of access onto the 1.9-2.1 GHz bands, as based on technology and service exclusivity evolving from GSM, industry actors had difficulty maintaining commitments to these operational rules in the aftermaths of the agreement in ETSI SMG#24bis. As it will be discussed below, ETSI SMG did not develop the internal mechanisms to monitor the technology preferences of its different participants and to ensure commitment to the operational rules agreed upon in ETSI SMG#24bis for the technical specifications of the radio access interface in UMTS. This exposed the fragility of operational rules for the deployment of UMTS in the 1.9-2.1 GHz bands based on the technology specifications agreed in ETSI SMG. As a result, operational rules of access and use of UMTS in the 1.9-2.1 GHz bands were soon contested inside and outside ETSI SMG. This high level of rivalry, similar to the high level of rivalry established after the collapse of the intellectual property coordination mechanism of the GSM MoU (1987), shaped preferences for individual exclusive forms of property based on UMTS in the 1.9-2.1 GHz band.

4.3.1 The Nature of Private Association

The agreement arrived at in ETSI SMG#24bis was contested, following a number of intellectual property disputes during 1998 and 1999. These disputes revealed the fragility of operational agreements for the 1.9-2.1 GHz band in the absence of strong collective choice rules to safeguard them. Two problems affected the nature of collective choice agreements in ETSI SMG in the aftermath of the agreement on the interface for UMTS. First, the decision-making procedures in ETSI SMG did not give participants enough time to exchange information about their technology preferences, between manufacturers and between manufacturers and operators. Second, and similar to the GSM MoU (1987), the agreement in ETSI SMG did not make any commitment to coordinating intellectual property, leading to internal disputes, especially between Ericsson and Qualcomm. The agreement for the deployment of UMTS in the 1.9-2.1 GHz band was reached only after an informal industry association – the 3G Partnership Project (3GPP) – was set up, in conjunction with a 3G Patent Platform Partnership that established principles of minimum cooperation on the essential technology capabilities of members. However, because the 3GPP was set up only after the formal adoption of operational rules based on UMTS in the 1.9-2.1 GHz band, rules of access and use on the bands remained structured on individual exclusive property.

Although agreement on the UMTS air interface was eventually reached, the standard development process in ETSI SMG carried a central dispute over essential IPRs in the specifications of the standard. This occurred because, under ETSI IPR Policy (1994), ETSI members had no responsibility to declare essential patents within a set time from the start of the standardisation process, as originally negotiated, and were only required to make them available, in bona fide, on “fair, reasonable and non-discriminatory” grounds (revisit *Section 4.2.2*). Under this policy, information exchanges about the technology preferences and technology capabilities of participants was minimal. Subsequently, during SMG#24 and SMG#24bis, when voting for the UMTS air interface was taking place, members did not declare any essential IPRs and, instead, opted for making broad IPR statements (ETSI/SMG(97)5 Part A)[124]. In addition, at SMG#24bis, promoters of either W-CDMA or TD-CDMA declared that the IPR

[124] At the meeting, the ETSI legal adviser compiled a list of companies that could hold UMTS radio interface patents relevant to the standardisation process, which was sent to the ETSI Secretariat in confidential form. Also, three German operators – T-Mobil, E-Plus Mobilfunk and Mannesmann Mobilfunk – put forward a position paper that expressed their “serious concern that patent issues, if at all, are not resolved in a satisfactory manner” (TDoc SMG 1061/97).

environment was strongly in favour of their respective solutions[125]. One of the most controversial position papers on IPRs in ETSI SMG was Qualcomm's – the US-based manufacturer that developed cdmaOne/cdma2000 – and who was claiming to hold a considerable portfolio in essential CDMA radio technologies (ETSI SMG(98)1 Part A). Although several proposals were made to license IPRs on fair and reasonable grounds, Qualcomm maintained its position on the premise that a single CDMA-based standard should be developed globally and that the standard should include its essential property. If Qualcomm did not agree to license its patents on fair and reasonable grounds, then, according to ETSI IPR Policy (1994), the standardisation process would have to start again based on alternative technology specifications. This situation reveals the fragility of operational rules of access and use of the 1.9-2.1 GHz bands based on UMTS. It also reveals that limited rules for exchanging information about technology capabilities and monitoring technology preferences were agreed in ETSI SMG. As the ETSI SMG Chairman, F. Hillebrand (2002) noted:

> "An ETSI Technical Committee has no leverage to resolve IPR issues. It can contribute to ease a solution by organising an open system specification process, where every interested company can register IPR so that they get negotiation power in licensing negotiations. This has been done by the whole UMTS specification process" (Hillebrand 2002: 212).

The fragility of the agreement was further exposed when the Commission of the European Union passed *Decision No 128/1999/EC on the Coordinated Introduction of a Third Generation Mobile and Wireless Communications System (UMTS) in the Community* of December 1998. Similar to the GSM Directive 87/372/EEC in the previous case study, the Decision would formalise operational rules of access and use agreed upon in ETSI SMG by adopting the technology specifications for UMTS, on an exclusive basis:

> ""[…] in line with the efficient use of radio frequencies […] Members States shall coordinate their approach with a view to authorising compatible types of UMTS systems in the Community" (Art 4, Decision No 128/1999/EC)

However, in the context of the dispute over essential intellectual property in ETSI as well as in the context of the liberalisation of telecommunications markets, the government of the United States interpreted Art. 4 of Decision No 128/1999/EC as a

[125] For instance, TDoc SMG 23/98 on Motorola's support of TD-CDMA and TDoc SMG 7/98 on IPR Licensing Policy Statement on behalf of the main W-CDMA promoters.

breach of the WTO Agreement on Telecommunications Services, by way of giving preference to UMTS systems as developed by ETSI. In response, in January 1999, the Commission published a letter to the US government, offering a clarification of the rules of exclusion stipulated in Decision No 128/1999/EC:

> "The UMTS Decision foresees the issuing of at least one UMTS license in each Member State to ensure the availability of an interoperable service and facilitate pan-European roaming for the benefit of consumers. The concept for UMTS and its eventual standard will be decided by industry with full participation from non-European industry. The UMTS Decision does not limit other 3G technologies in the European market as Member States, in accordance with their national licensing schemes, are free to authorise them next to UMTS if economic operators would propose this" (EC 1999).

Nevertheless, the commitment of industry actors to UMTS was, once again, achieved outside the formal parameters of decision-making in ETSI and the wider policy context of the European Union. First, in order to avoid continued deadlocks, F. Hillebrand (2002), the Chairman of ETSI SMG, proposed the creation of the 3G Partnership Project as an industry association of standardisation bodies promoting UMTS based on GSM from around the world (Hillebrand 2002: 215). Within this informal industry association, members could set up minimum mechanisms for coordinating their intellectual property, as initially discussed but not arrived at in ETSI SMG. The idea came from members of ETSI SMG and had a stronger representation and position from the GSM MoU Association[126]. The group stated that their rationale was "to limit the liability of the proposed standard to excessive IPR demands" (SMG TDoc 241/98). The group proposed the creation of the 3GPP Patent Platform as a middle ground between a patent pool and the existing IPR Policy in ETSI (SMG TDoc 608/98).

Essentially, the patent platform broke the deadlock regarding the technology systems structuring rights of use on the 1.9-2.1 GHz band[127]. It allowed for a non-exclusive partnership where both licensors and licensees could become members, but where no

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[126] The participating companies were: Alcatel, Analog Devices, Bosch, Cegetel, CSEM/Pro Telecom, Ericsson, France Telecom, Fujitsu, Lucent Technologies, Mannesmann, Matsushita, Mitsubishi, Motorola, NEC, Nokia, Nortel, NTT DoCoMo, Siemens, Sony, T-Mobil, Telecom Finland, Telecom Italia, Texas Instruments. At the meetings, representatives from ETSI, ETNO and the GSM MoU Association were present.

[127] The idea of the patent platform was considered in line with competition law within the EU, as well as in other jurisdictions, since its members were not bound to create exclusive patent pools that could lead to dominant positions (Choumelova 2003).

bundling or pooling of patents would take place and where licensors were given the freedom to license outside the partnership (3GPP 1999, Choumelova 2003). More importantly, the 3G Patent Platform would act as a voluntary evaluation and certification body for essential patents in third generation mobile communications. However, the project was agreed in 3GPP only after Ericsson and Qualcomm entered into a cross license agreements for their CDMA-based portfolios, abandoning the litigation and supporting the creation of a global family of standards – IMT-2000[128] – ensuring minimum harmonisation of third generation systems but maintaining three CDMA-based modes of operation: cdma2000, W-CDMA and TD-CDMA[129].

The establishment of the 3G Partnership Project (3GPP) and the 3G Patent Platform reveals two important aspects about the strategies of industry actors for the coordination of economic activity in the 1.9-2.1 GHz band. First, the strategy of the main developers in ETSI SMG was to consolidate their presence in the mobile communications market by replicating positions of rivalry and excludability created with the deployment of GSM in the 900 MHz band. *Figure 4.4* provides a visual representation of global technology transfers in radio communications services and equipment from January 1995 to December 1999[130]. From a visual standpoint, the network representation confirms the nodal role of manufacturers with essential intellectual property in GSM and UMTS in the transfer of technology capabilities from a global core to the periphery. The network metrics are provided in Table 4.5 and confirm that positions of rivalry and excludability in the delivery of mobile communications at the global level were maintained since the deployment of GSM. As a representation of the number of exchanges in the network, the high degree centrality logged by Motorola, Siemens and Ericsson reveals their key positions in the transfer of intellectual property. Similarly, as a measure of influence in the networks, Motorola, NTT – which collaborated closely with Ericsson to operate the first networks for third generation mobile communications

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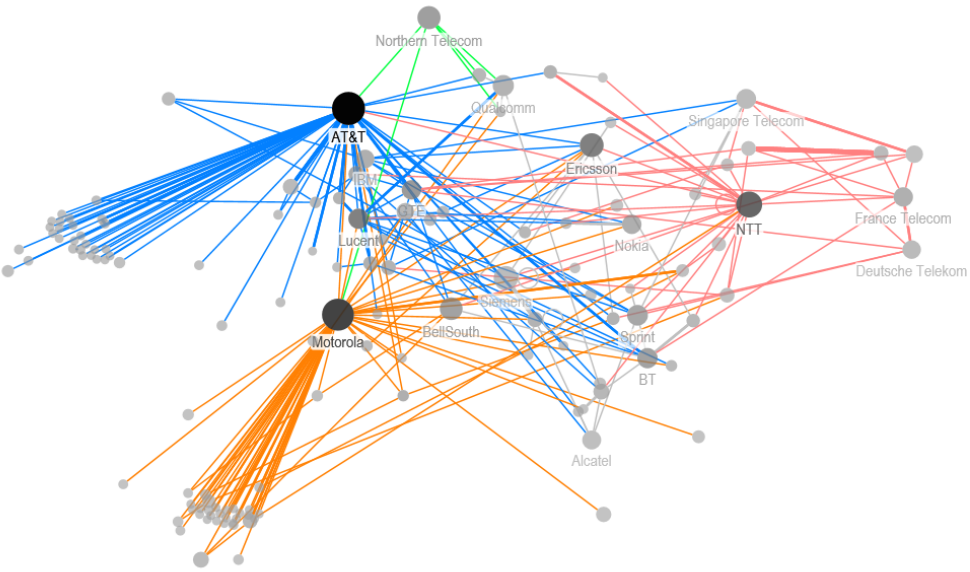
[128] Future Public Land Mobile Telecommunication Systems (FPLMTS) was renamed IMT-2000 by the ITU (revisit *Section 4.2.1*).

[129] This family of standards, which is perceived as a global compromise, resulted largely from consideration of technology path from second generation mobile communications around the world, particularly from the operators' point of view, rather than a reflection on the patent disputes. For more information on the harmonizing efforts of operators, see K. Zsigo (1999).

[130] This visual representation applied a filter of the eigenvector centrality at 0.0025, which eliminates one-off transfers of outliers. However, *Table 4.5* gives the main network metrics prior to the application of any visual filters.

systems based on the W-CDMA radio network and the evolved GSM core network – and Ericsson score some of the highest levels of eigenvector centrality.

Figure 4.4 Network Visualisation of Technology Transfers, Global Strategic Alliances, Jan 1995 - Dec 1999



Source: Based on Thompson Reuters, SDC Platinum Database, Accessed Dec 2013

Table 4.5 Network Analysis Metrics, Global Strategic Alliances, Jan 1995 - Dec 1999

Measures	**Network Analysis of Strategic Partnerships Global Telecommunications Sector Jan 1995 – Dec 1999**
No log entries	3,250
No nodes	1,505
Mean degree centrality	2.1
Mean eigenvector centrality	0.001
Mean betweenness centrality	837
Max degree centrality	AT&T (59), Motorola (55), NTT (35), Siemens (30), Ericsson (29)
Max eigenvector centrality	AT&T (0.035), Motorola (0.026), NTT (0.020), Ericsson (0.016), Lucent Technologies (0.016)
Max betweenness centrality	AT&T (90,954), Motorola (77,530), NTT (49,299), Northern Telecom (33,174), Lucent Technologies (30,863).

Source: Based on Thompson Reuters, SDC Platinum Database, Accessed Dec 2013

The second aspect that the organisation of industry activity in ETSI SMG reveals is the fragility of operational rules based on technology exclusion and service exclusion in conditions when collective choice rules do not reflect the participation of all resource users (i.e. service operators) and do not ensure basic mechanisms of information exchange about technology preferences or technology capabilities. The next section looks at the impact of this rule configuration in ETSI SMG on the property arrangements established in the 1.9-2.1 GHz bands, upon the deployment of third generation mobile communications systems based on UMTS.

4.3.2 The Nature of Property Arrangements in the 1.9-2.1 GHz Frequency Pool

The negotiations that took place in ETSI SMG reveal important considerations about the relationship between the configuration of industry actors and the property arrangements that resulted from the deployment of technology systems based on UMTS in the 1.9-2.1 GHz band across Europe in the late 1990s. *Table 4.6* provides a summary of the configuration of rights at operational and at collective choice level that formed the bundle of property arrangements in the 1.9-2.1 GHz band.

Table 4.6 The Configuration of Property Arrangements in the 1.9-2.1 GHz Frequency Bands for the Deployment of UMTS Systems in the late 1990s

Property Right		**Property Arrangements in the 1.9-2.1 GHz Frequency Band based on UMTS**
Operational Rights	*Access*	The right to enter the radio resource is granted based on membership in a geographic club (CEPT) and on membership in a technology club (ETSI SMG).
	Use	The rate of withdrawal from the radio is embedded in the technical specifications of the standard (UMTS). Members with technology capabilities in the core network of GSM will maintain the same rate of withdrawal in the new resource, because UMTS is based on an evolved core network for GSM. The new radio access technology for UMTS does not change withdrawal rate among members either, because both W-CDMA and TDMA are included in the final specification.
Collective Choice Rights	*Management*	Majority voting inside ETSI SMG provides some basis for agreement in conditions of increased heterogeneity of capabilities. It contributes to the quick adoption of operational rules of use based on the same withdrawal pattern as in GSM, by passing the technology preference for "evolutionary" UMTS as desired by industry rather than the technology preference for "revolutionary" UMTS as desired by the public actor. However, the equal representation of resource users, particularly service operators, in developing operational rules is more limited in ETSI SMG than in GSM-CEPT. Internal monitoring of technology preferences of voting members is also limited in ETSI SMG. Credible commitments to accessing technology capabilities of other members on fair and reasonable grounds, as a way of sharing withdrawal rights from the 1.9-2.1 GHz band, is also limited.
	Exclusion	The right to determine who has access to the 1.9-2.1 GHz band is well defined in ETSI SMG, based on geographic representation in CEPT and adoption of technology specifications devised in ETSI SMG (UMTS and GSM). Internalisation of outsiders is minimal.

At the operational level, it reveals that the rights resulting from agreements on the main network architecture for UMTS systems was based on principles of exclusion. On the one hand, exclusion of use as derived from those technology specifications that were not based on the core GSM network, which UMTS systems were also based on. In addition, because the new radio access interface for UMTS systems included both TD-CDMA and W-CDMA, its adoption did not challenge the configuration of rivalry and excludability achieved in the 900 MHz band, as reported in the previous case study. On the contrary, it replicated it in another frequency band – i.e. 1.9-2.1 GHz band – particularly as the two technology solutions, supported by the most established developers across the CEPT, made it into the final radio access interface. On the other hand, exclusion of access was achieved on a geographic basis – i.e. only companies located in the CEPT could vote in ETSI Technical Committees – and the technical specifications arrived at in ETSI SMG were based on the exclusive deployment of third generation mobile communications services in the 1.9-2.1 GHz bands.

However, at the collective choice level, there was less coordination between members, which weakened the operational arrangement arrived at in ETSI SMG. Although operators and manufacturers had equal rights of participation in ETSI SMG, operators did not take part in system specification design as in the previous case study (GSM-CEPT). In addition, mechanisms for exchanging information about technology preferences for the radio interface as well as mechanisms for ensuring commitments to the technology specifications arrived at in the radio interface, as exemplified by the position of Qualcomm, were limited in ETSI SMG. Established in 1999, the 3G Partnership Project and the 3G Patent Platform occurred only after operational rules of use of the UMTS systems in the 1.9-2.1 GHz band were challenged, internally, by Qualcomm and after those operational rules – based on technology and service exclusivity – were legitimated in EU legislation. Thus, although industry actors approved operational rules in ETSI SMG, internal contestation of the configuration of those rules remained high – unless until the establishment of the 3G Patent Platform – and, subsequently, informed preferences for individual exclusive rights in the 1.9-2.1 GHz band, based on technology exclusivity and service exclusivity.

4.4 Conclusions

This case has traced the definition of operational rules for the 1.9-2.1 GHz frequency band for the deployment of third generation mobile cellular communications systems by industry actors organised in ETSI. The case makes three contributions to the specialist literature looking at the organisation of authority in transnational commons on the one hand, and at the attributes of groups most likely to facilitate cooperation on the other hand. First, the case suggests that industry actors with symmetric economic preferences and asymmetric technology capabilities can solve first level problems of organisation for devising operational rules in a transnational common pool. In our case, they do so in ETSI, which was established in order to represent, in its decision-making, the diversified distribution of capabilities among industry actors in the CEPT – i.e. turnover weighted decision making. This evidence confirms theoretical assumptions in the study of transnational common goods, which propose that heterogeneity of capabilities – particularly if these are distributed across a small number of private actors – can facilitate private coordination. In our case, the centrality of developers with considerable technology capabilities in GSM systems, contributed to the development of technology solutions for harvesting the 1.9-2.1 GHz band that would replicate the situation of rivalry and excludability in the 900 MHz band (revisit *Chapter 3*). This aspect is linked to the second contribution of this case to the specialist literature on the distribution of authority in transnational commons. In contrast with the previous case, the Commission of the European Union exhibits clear competences in regulating telecommunications markets as well as a clearly defined preference for "revolutionising" the third generation of mobile communications, rather than evolving it from GSM. Because this "revolutionary" approach would change positions of rivalry and excludability in the radio spectrum, private actors initiate the definition of an "evolutionary" system from GSM in ETSI.

The third contribution of this case is to our understanding of the ability of private actors – already organised in ETSI in order to define a replica of operational rules in the 900 MHz band for GSM – to sustain commitments to these operational rules. Surprisingly, levels of internal rivalry in ETSI stayed high and, subsequently, industry actors did not communicate their technology preferences, or information about their technology capabilities (e.g. essential patents), prior to the voting on the standard. As in the previous case study (*Chapter 3*), the result was a deadlock, which was solved by cross licensing agreements after operational rules embedded in the standard were put to the vote. Due to these weak levels of commitments, operational rules were, once again, legitimised by the public actor in Commission Decision 128/1999/EC.

Chapter 5. Regulating the 800 MHz Bands: Devising Collective Choice Rules in Global Pools

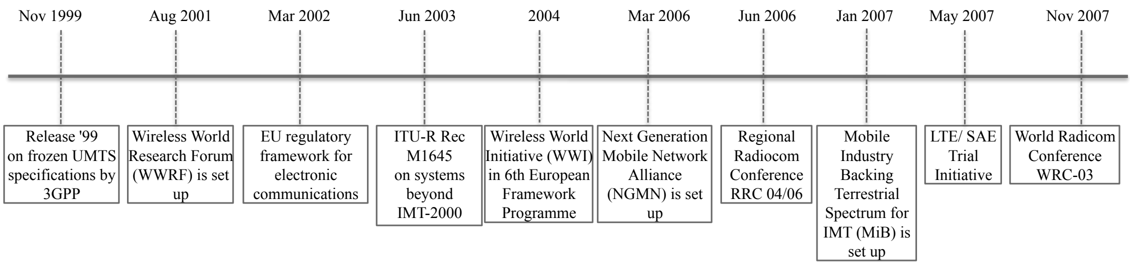
This chapter traces the process of redefining property arrangements in the 800 MHz band in Europe in the late 2000s, from an original allocation at regional level to broadcasting services to a reallocation at the global level to broadcasting and mobile communications services on a co-primary basis. The case of the regulation of the 800 MHz band in the late 2000s puts forward a new distribution of preferences among public and private actors.

On the one hand, this case reveals a transnational public actor, in the form of the Commission of the European Union, with clear authority in regulating communications markets and new competence in harmonising spectrum policies across Member States. The authority of the European Commission is exemplified by its active role in driving the digitisation process of broadcasting services, which were occupying a portion of the radio spectrum that included the 800 MHz band. In the switchover process from analog to digital broadcasting services, part of the radio frequencies occupied by analog transmissions could be released, producing a "digital dividend". However, in contrast with the previous case study, the public actor did not express a preference for the reallocation of this "digital dividend" to a communication service or to a technology configuration. In this circumstance, industry actors negotiated operational rules for the 800 MHz band outside the policy venues established around this public actor.

On the other hand, this case reveals a new distribution of economic interests and technology capabilities among industry actors interested in the reallocation of the digital dividend bands. The case shows considerable heterogeneity in the economic interests of the broadcasting industry on the one hand, and the mobile communications industry on the other hand, as well as differences in the economic interests of operators and developers within the mobile communications industry after the telecommunications "market crash" of the early 2000s. This heterogeneity of economic interests is reinforced by considerable heterogeneity of technology capabilities among developers and operators in the mobile communications industry, following the diversification of technology standards used to harvest the radio resource. Theoretical expectations based on the study of local common pool resources would indicate that this distribution of diverse interests and diverse capabilities is one of the most unlikely configurations to result in private cooperation without the intervention of a public actor.

However, this case study reveals that industry actors are able to coordinate in order to reallocate access and use of the 800 MHz band even in conditions of diversity of economic interests and technology capabilities. Specifically, the case shows that industry actors in the mobile communications industry organised in order to overturn, at the global level (WRC-07), an allocation of the 800 MHz band made in favour of the broadcasting industry, at the region level (RRC-06), within the span of just over one year. The case traces the process by which actors in the mobile communications industry achieved the reallocation of the 800 MHz band under new property arrangements. *Figure 5.1* indicates the main events in this process, which, once again, span over a decade of negotiations.

Figure 5.1 Timeline of Main Events in the Regulation of the 800 MHz Band in the 2000s



The chapter shows that there are two important steps taken by industry actors in the mobile communications sector in order to accommodate and manage their heterogeneity of interests and capabilities. First, rules of collective management for technology systems in the 800 MHz band were negotiated based on the early participation of both operators and developers in the decision-making process as well as based on mutual monitoring of system development across the two industry groups. Second, rules of operation in the 800 MHz band were negotiated under flexible consensus between operators and manufacturers, whereby rules of use were not defined in relation with the adoption of a strict set of technology specifications (i.e. technology exclusivity), as preferred by operators. Similarly, rules of access were defined in relation with service primacy in the band as preferred by both operators and manufacturers. In this case, operators had the flexibility to independently define the rate of use of the radio resource, by selecting from a number of mobile communications systems (or "generations") based on considerations of market demand. Similarly, in this case, manufacturers had the assurance that at least one of the their technology capabilities would be selected for deployment by operators, as long as the communication systems was based on technology inclusion (co-existence) rather than technology exclusion. Because such a technology configuration would reduced levels of rivalry among members of the same industry association (Wireless World Research Forum), it allowed for the definition of flexible rules of use inside the frequency pool at 800 MHz, while ensuring that mobile communications services benefited from primacy of access at the global level. Because primary status is the highest level of protection against non-interference in radio communications, the property arrangements that resulted from this configuration of rules resembled principles of common (flexible use) and exclusive (primary access) property. This configuration of property rights differs from the previous case studies, where property arrangements are based on individual, technology exclusive and service exclusive property.

5.1 The Formation of Actor Strategies in the Wider Governance of Electronic Communications

This section follows the formation of actor strategies prior to the negotiation of operational and collective choice rules in the 800 MHz frequency band in the late 2000s. It argues that both public and private actors had to reconsider their position regarding the configuration of property arrangements in the radio resource as a result of two factors: a) the process of digitisation of communications services, which pushed forward an agenda for convergence of broadcasting, telecommunications and information technology services and b) the financial instability of the telecommunications industry, which resulted in the “telecoms crash” of the early 2000s. For transnational public actors, such as the European Commission, these structural factors opened an opportunity to renew the agenda for liberalisation of electronic communications away from the “managed competition” approach of the 1990s and towards an “integrated approach” for converged services in the 2000s (Hancher and Larouche 2011). Because the agenda for convergence was associated with the digitisation process of electronic communications services, it raised questions about its distributive and re-distributive effects on the allocation of the radio resource in spectrum bands where analog broadcasting services were considered for digitisation, such as in the 800 MHz band. For industry actors in the broadcasting sector, the process of digitisation and convergence threatened positions of reduced rivalry and uncontested excludability in the 470-862 MHz band (i.e. the UHF band), established since the 1961 Stockholm Agreement on the transnational allocation of colour television broadcasting services in Europe. For industry actors in the mobile cellular communications sector, which had digitalised since the introduction of second generation systems such as GSM, the process of convergence occurred simultaneously with the financial collapse of the telecommunications sector and, subsequently, challenged business models based on the purchase of individual and exclusive rights in new spectrum bands. Overall, the financial instability of the telecommunications market, which challenged the position of the established mobile cellular communications industry, coupled with the convergence of electronic communications systems, which challenged the position of the established broadcasting industry, triggered a shift in strategies away from an interest in purchasing exclusive rights in new spectrum and towards the reorganisation (i.e. refarming) of already acquired spectrum along more flexible rules of access and use of the radio resource.

5.1.1 The Structure of the System of Governance in Electronic Communications

In the early 2000s, the system of governance for electronic communications – i.e. broadcasting, telecommunications and information technology – had a different structure than the hierarchical, minimally coordinated order of the 1980s[131] (Genschel and Werle 1993). There are two explanations for this change in the governance structure of electronic communications in developed markets. First, the process of digitisation, by which content of any type – voice, image, data – is packaged and delivered via the same system, challenged hierarchical forms of organising broadcasting and telecommunications industrial relations. The process of digitisation is thus associated with the convergence of distinct services in broadcasting, telecommunications and information technology, which traditionally developed in hierarchical relations of

[131] Revisit *Section 3.1* for a discussion on the hierarchical structure of the telecommunications sector in Europe in the 1980s, coupled with minimal coordination across borders.

production and distribution and were now challenged by a blurring of boundaries between them and by their reconfiguration into "bits" and "transport"[132]:

> "[…] from the standpoint of firms, they used to be in silos, with a telephone firm and various TV channels, but now the same delivery system can deliver bits, which could be a voice call or it could be broadband or it could be video or it could be almost anything" (Cave 2012: 210).

Second, with digitisation, electronic communication systems are developed and deployed differently than traditionally separate systems such as telephone lines and television aerials, leading to an intensification of standardisation at transnational and international level and challenging the traditionally minimal coordination of the industry across borders (Schmidt and Werle 1998). An example of this intensification of transnational and international standardisation is the IMT-2000 family of global standards[133] for third generation mobile cellular communications, which coordinated competing technology specifications produced by different transnational standardisation bodies under a single definition of services provided by the ITU (revisit *Chapter 4*).

However, the process of digitisation did not and does not produce the same degree of convergence as well as the same level of transnational coordination across the different industries that make up the wider electronic communications sector. In addition, there are different causes for the uneven coordination and convergence of industries in the wider electronic communications sector. In fact, in the early 2000s, the process of digitisation, convergence and transnational coordination differed considerably between the broadcasting industry, the mobile cellular communications industry and the information technology industry.

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[132] Asked by the Select Committee on Communications in the House of Lords whether convergence of electronic communications could mean the bundling of any type of communication services, M. Cave responded: "Yes, in a sense ultimately it is bits and it is transport" (Cave 2012: 221). As it will be discussed below, this is also the approach adopted by the European Commission in the 2002 Electronic Communications regulatory framework.

[133] Although it is generally referred to as an international family of standards, IMT-2000 is a set of technical recommendations for the delivery of global third generation mobile communication systems, agreed at the level of the ITU. As discussed in the previous chapter, IMT-2000 had three member standards: UMTS/W-CDMA, CDMA2000, UMTS/TDMA. Following a number of revisions on the specifications throughout the 2000s, four other members were added. From the 2G+ family, the EDGE and DECT standards were added. From the 3G+ family, mobile WiMAX and HPSA were later added.

The limitations of convergence are evident in the process of digitisation of the broadcasting industry in Europe in the early 2000s. At community level in the European Union, the broadcasting industry adopted a single standard for digital television (DVB) in the late 1990s[134]. However, the development of the digital television standard did not lead to an inevitable deployment of digital television services or an inevitable creation of a single market for digital broadcasting in the community.

Table 5.1 The Digital Television Market in the EU, 2002

	Total HH	Total Digital TV HH		Cable DTV		Satellite DTV		Terrestrial DTV	
		TV HH	%	TV HH	%	TV HH	%	TV HH	%
Austria	3.3	0.36	10.7%	0.07	2.1%	0.29	8.7%	0.00	0.0%
Belgium	4.3	0.23	5.2%	0.22	5.0%	0.01	0.2%	0.00	0.0%
Denmark	2.4	0.92	38.9%	0.55	23.6%	0.36	15.3%	0.00	0.0%
Finland	2.3	0.22	9.4%	0.04	1.6%	0.17	7.3%	0.01	0.5%
France	25.1	4.97	19.8%	0.95	3.8%	4.02	16.0%	0.01	0.0%
Germany	37.9	4.14	10.9%	1.94	5.1%	2.21	5.8%	0.00	0.0%
Greece	3.6	0.22	6.0%	0.00	0.0%	0.22	6.0%	0.00	0.0%
Ireland	1.3	0.32	24.4%	0.06	4.4%	0.26	20.0%	0.00	0.0%
Italy	20.1	3.13	15.6%	0.02	0.1%	3.11	15.4%	0.00	0.0%
Luxembourg	0.2	0.01	5.3%	0.00	1.0%	0.01	4.2%	0.00	0.0%
Netherlands	7.1	1.16	16.5%	0.45	6.4%	0.69	9.8%	0.02	0.3%
Portugal	3.6	0.34	9.6%	0.04	1.1%	0.29	8.0%	0.02	0.5%
Spain	12.8	3.21	25.1%	0.05	0.4%	2.78	21.8%	0.38	3.0%
Sweden	4.6	1.44	31.6%	0.46	10.0%	0.84	18.4%	0.15	3.2%
UK	26.3	11.51	43.8%	3.23	12.3%	6.22	23.7%	2.06	7.8%
TOTAL EU	154.73	32.2	20.8%	8.1	5.2%	21.5	13.9%	2.6	1.7%
US	118	44.95	38.1%	21.8	18.5%	22.55	19.1%	0.6	0.5%
Japan	41.9	6.7	16.0%	0	0.0%	6.7	16.0%	0	0.0%

Source: EC (2003), Annex I

[134] The digital transmission of television signal via different communications infrastructures – terrestrial, satellite and cable – was regulated under Directive 95/47/EC, which stipulated that, in fully digital, television services should "use a transmission system which has been standardised by a recognised standardisation body" (Art 2c, Directive 95/47/EC). In this case, the delegated body was the Digital Video Broadcasting (DVB) Consortium that produced, in the late 1990s, three digital television standards for the respective transport networks: DVB-T (terrestrial), DVB-S (satellite) and DVB-C (cable). Levy (1997) and Michalis (1999) analyse the decision-making process that led to the adoption of Directive 95/47/EC as well as the reasons that contributed to the low rate of adoption and deployment of digital broadcasting services in Europe. For instance, Levy (1997) argues that national institutional structures, underpinned by the traditional politicisation of the broadcasting sector in Europe, contributed to the unwillingness of broadcasting operators to upgrade to digital systems of signal transmission.

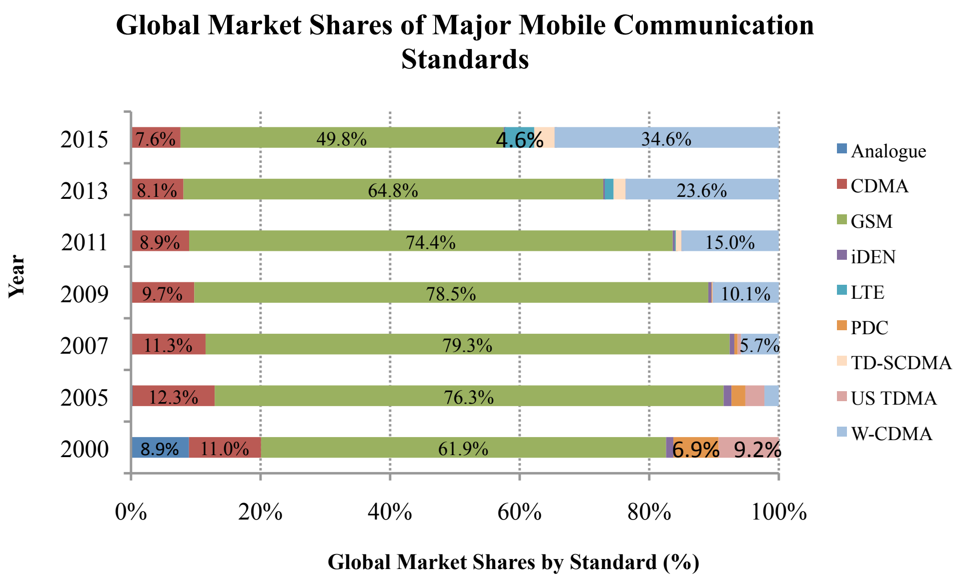
On the contrary, *Table 5.1* reveals that, in the early 2000s, the digital television market was fragmented across different transport networks – terrestrial, cable or satellite – as well as across different member states of the European Union. In this case, the uneven digitisation of broadcasting services across networks was not triggered by coordination problems in the development of a digital standard per se, but by limited agreement over the implementation of conditional access systems and gateway systems, coupled with limited willingness to invest in the reorganisation of the radio resource and the physical infrastructure (Levy 1997).

Thus, in the case of the broadcasting sector, the process of digitisation would require fundamental changes to their business model. On the one hand the switchover from analog to digital transmission would have considerable redistributive effects in the radio resource because, with digitisation, "five to eight digital channels can be fitted in the same space occupied by one analogue channel" (EC 2003: 6). On the other hand, the switchover from analog to digital transmission would have considerable redistributive effects in the broadcasting market because, with digitisation, the broadcasting value chain would be open to new entrants and new services (EC 2003: 7).

Similarly, the intensification of transnational and international standardisation in mobile telecommunications did not produce an immediate deployment or take up of third generation mobile communication services in the IMT-2000 family of standards. *Figure 5.2* reveals that, instead of replicating the growth patterns of second generation mobile communications around the world, third generation systems in the IMT-2000 family of standards – CDMA and W-CDMA[135] – had a total share of less than 15% of the global market for mobile communications in the mid 2000s. In fact, in mid 2000s, the GSM second generation standard had the largest share of the global market for mobile telecommunications, at over 70% of the market.

[135] As described in the previous chapter, Chapter 4, W-CDMA is the radio specification of the UMTS standard developed by 3GPP, whereas CDMA – or cdma2000 – is the radio specification developed by 3GPP2 for third generation mobile communications systems. Whereas W-CDMA was developed and deployed in Europe and Japan, cdma2000 was developed and deployed primarily in North America.

Figure 5.2 Global Market Shares of Major Mobile Communications Standards



Source: Based on WCIS Database, Informa, Accessed Dec 2012

As in the case of the broadcasting industry, coordination over the development of the IMT family of standard did not trigger immediate implementation, deployment or take up of third generation mobile communications services. Several market considerations have impacted this process. First, setting up interconnection and roaming agreements between operators of third generation mobile communications systems belonging to the same family of standards – i.e. IMT-2000 – was more costly than envisioned by international standardisation organisations such as ITU-R[136] (Bohlin et al 2007: 241). Second, reduced cooperation over the development of multimedia content to be delivered over third generation mobile communication services, coupled with reduced interoperability of mobile data services delivered across third generation networks in different countries, limited the added services offer of third generation networks compared with established second generation (i.e. 2G and 2.5G) networks (Weber et al 2004: 383-387). Bohlin et al (2007) argue that this situation perpetuated "a vicious cycle in which the lack of content and infrastructure mutually reinforce one another, heightened by the absence of a clear idea about the kind of content that customers might

[136] One of the central considerations for increased costs of interconnection was the requirement to produce multi-band mobile devices that would pick up signals emitted from third generation systems operating in different frequency bands around the world. Thus, the global roaming requirement for membership of the IMT-2000 family of standards imposed additional costs of development and interconnection (Feldman 2005: 69, Rosenbrock 2002: 239).

want" (Bohlin et al 2007: 239). K. H. Rosenbrock, Director General of ETSI in the early 2000s, confirmed that uncertainty over the type of multimedia content to be delivered on third generation networks led to over 5,700 change requests being proposed to the UMTS standard after the specifications were frozen by 3GPP in 1999 (Rosenbrock 2002: 245). Lastly, the costs of purchasing access to new spectrum and the costs of investing in new network infrastructure for third generation systems outweighed the marginal improvements on added data services already provided by 2.5G networks. These discrepancies resulted in considerable variation in the cost of licensing radio spectrum in the 1.9-2.1 GHz bands for third generation mobile communications systems in Europe[137] and contributed to the accumulation of debt by telecommunications operators, leading to the telecommunications market crash of 2001 (Gruber 2001, Klemperer 2001, The Economist 2002). However, although the design and inconsistent application of the auctioning process across developed telecommunications markets in Europe slowed down the migration from second generation to third generation mobile communications systems, it was by no means a sufficient factor for restricted investment in third generation communications networks in Europe. Instead, the significant duplication in communication services between 2.5G networks and 3G networks, coupled with the lack of multimedia content to be delivered as added services on 3G networks, contributed significantly to the slow migration from second generation to third generation mobile communications systems (revisit *Chapter 4*). This slow migration from second to third generation mobile communications systems raised questions about the extent of reorganisation or redistribution of the radio resource prescribed for third generation networks in conditions of low occupancy rates.

Overall, digitisation created the possibility for convergence of services and networks as well as for intensification of transnational standardisation of systems in electronic

[137] Although the pricing of the radio resource for the deployment of third generation mobile communications systems is regarded, in the specialist literature, as one of the necessary conditions for the telecoms crash of 2002, it is by no means a sufficient condition for the telecom crash. Discrepancies between the pricing of radio spectrum across EU Member States have been identified as an important factor. Klemperer (2002) note that revenues from licensing spectrum in the 1.9-2.1 GHz frequency bands varied from €45 per capita in Belgium or Greece to over €600 per capita in Germany or the United Kingdom. Similarly, Cowhey et al (2008) and Gruber (2001) noted that the design of the auctioning processes could also distort valuations of the radio resource, causing telecommunications operators to overbid for access, with intensions to hoard the radio resource rather than invest in immediate network development.

communications but it did not and could not ensure their consistent implementation across different industries or across different states. The case of the broadcasting and the mobile communications industry in the early 2000s reveals that the two sectors were in different stages of the digitisation process and responded with different market dynamics to this process. Most importantly, the case of the broadcasting and mobile communication industry in the early 2000s reveals that changes in technology – i.e. digitisation – cannot inevitably lead to market efficiency or market growth and, as a result, can challenge established positions of rivalry and excludability in the radio resource that facilitates these markets. In the case of the broadcasting sector, the migration from analog to digital transmission would bring a radio spectrum "gain" – i.e. five to eight times more resource made available – that would challenge positions of exclusivity in bands traditionally allocated to broadcasting services. In the case of the mobile communications sector, the migration from second to third generation systems challenged established positions of rivalry derived from the prescription of technology specifications – i.e. GSM or UMTS – in bands with low utilisation rates. The next sections discuss the extent to which public and industry actors responded to these pressures by reformulating their strategies for the configuration of access and use of the 800MHz frequency band populated by terrestrial broadcasting services and considered for digitisation in the mid 2000s in Europe. The next sections show that, although the European Commission utilised the agenda for digitisation to renew the regulation of electronic communications markets in Europe, it took a reserved approach to specifying technology or service preferences for the redistribution of the radio resource considered for digital switchover. In contrast, the broadcasting and mobile communications industry expressed clear yet diverging preferences for a particular configuration of recipients and rules in the radio resource considered for digital switchover.

5.1.2 The Initial Position of the Public Actor

In the early 2000s, the European Commission was an established public actor with unambiguous competences in regulating electronic communications markets in the European Union. Deriving these competences directly from treaty changes as well as from the application of the Open Network Provision Framework (ONP) of the 1990s, the European Commission articulated its competences with reference to the process of liberalisation of networks and services (revisit *Chapter 4*). However, as Hancher and

Larouche (2011) noted electronic communications law evolved from a "formalistic model" for ensuring market access in the ONP to an "integrative model" for ensuring competition in a new regulatory framework for electronic communications adopted in the early 2000s (2011: 747). Although this new framework rested on principles of competition ("effective competition") and proportionate regulation ("technology neutrality")[138], its core was the convergence of electronic communications derived from the process of digitisation:

> "The convergence of the telecommunications, media and information technology sectors means all transmission networks and services should be covered by a single regulatory framework. […] It is necessary to separate the regulation of transmission from the regulation of content" (para 5, Directive 2002/21/EC).

In this context, there is little doubt that the European Commission pursued the agenda for convergence of electronic communications networks and services by direct reference to the process of digitisation of these sectors and, particularly, by direct reference to the broadcasting sector as requiring aligning, through digitisation, with the rest of electronic communications industries that had already been through the process, such as the mobile communications industry (EC 1999, EC 2003). In fact, Directive 2002/21/EC resolved any tensions between digitisation – as a redistributive process requiring some level of re-regulation of the radio resource/market – and technology neutrality[139] – as a non-discriminatory principle that requires the removal of regulation distorting market forces – in favour of the digitisation agenda:

> "The requirement for Member States to ensure that national regulatory authorities take the utmost account of the desirability of making regulation technology neutral […] does not preclude the taking of proportionate steps to promote certain specific services where this is justified, for example digital television as a means for increasing spectrum efficiency" (para 18, Directive 2002/21/EC).

[138] The European Commission identified five principles for regulatory action for converged electronic communications: a) the promotion of competition in the European market for communications services to benefit the European citizens and to consolidate the internal market in a converging environment; b) minimum harmonization and the reduction of regulation where policy objectives are achieved through competition; c) legal certainty; d) technology neutrality; e) enforced as closely as possible to the regulated activities at global, regional and national level (COM(1999) 539).

[139] Directive 2002/21/EC provided the first formal definition of the principle of "technology neutrality" in electronic communications law in the EU. Technology neutrality was defined as a responsibility to "neither impose nor discriminate in favour of the use of a particular type of technology" (para 18, Directive 2002/21/EC).

However, this approach to the regulation of the electronic communications sector required two types of competences that the European Commission did not equally possess at the time. On the one hand, it required competences in redistributing the market for electronic communications, which the European Commission already had and which were used to re-regulate the sector in electronic communications networks[140] and electronic communications services[141], similar to the "transport" and "bits" approach explained by Cave (2012) (Art 2, Directive 2002/21/EC). On the other hand, it required competences in redistributing the radio resource harvested by industry for the delivery of electronic communications, which the European Commission did not have and which remained in the competence of Member States. In fact, Decision 676/2002/EC, which was aimed at establishing a regulatory framework for radio spectrum policy together with the legislative package on industry convergence, maintained the same jurisdictional boundaries between Member States and the Commission (Art 5), recognised the remit of the CEPT in harmonising radio frequency allocations (Art 4) and formalised practices of coordinating policy approaches[142] at EU level (Art 1) similar to the case of the 900 MHz band for the delivery of GSM or the 1.9-2.1 GHz band for the delivery of UMTS.

In this case, the European Commission had a strong position in favour of the digitisation of terrestrial broadcasting services but, due to this division of competences, did not express a definite preference for the redistribution of the radio resource to be released after the switchover from analog to digital broadcasting. This position of the European Commission is particularly relevant because the "digital dividend" – i.e. the radio resource released after the switchover from analog to digital broadcasting – was

[140] 'Electronic communications networks' are defined as "transmission systems and, where applicable, switching or routing equipment and other resources which permit the conveyance of signals by wire, by radio, by optical or by other electromagnetic means […] to the extent that they are used for the purpose of transmitting signals, networks used for radio and television broadcasting, and cable television networks, irrespective of the type of information conveyed" (Art 2a, Directive 2002/21/EC).

[141] 'Electronic communications services' are defined as "a service normally provided for remuneration which consists wholly or mainly in the conveyance of signals on electronic communications networks, including telecommunications services and transmission services in networks used for broadcasting, but exclude services providing, or exercising, editorial control over content transmitted using electronic commuunications networks and services" (Art 2b, Directive 2002/21/EC).

[142] Decision 676/2002/EC established a Radio Spectrum Policy Group that would assist the Commission for coordinating these policy approaches (Art 3).

situated in a "prime" portion of the radio resource below 1 GHz (400 MHz to 800 MHz) where electronic communications benefit from stable penetration rates and long ranges (i.e. less physical infrastructure). In fact, throughout the 2000s, when the Radio Spectrum Policy Group of the European Commission conducted several rounds of industry consultations, the Commission maintained a reserved position regarding the reorganisation of this prime radio resource:

> "A major allocation issue for all Member States is how to reallocate the "digital dividend": that is the spectrum released when analogue broadcasting is finally closed down. […] So far, the momentum is towards keeping the spectrum within broadcasting, though the potential alternative use of the spectrum by other services is being developed in various fora" (EC 2003: 21-22).

Even after the industry consultation process on the implications of the switchover, conducted by the Radio Spectrum Policy Group from 2004 to 2006, the European Commission did not make a clear recommendation for the amount of radio resource to be reorganised[143], the industry recipients of this reorganisation[144] or the configuration of operational property arrangements (rights of access and rights of use) in this resource (EC 2007: 9). Instead, the Commission opted for the identification of three main "application clusters" – broadcasting networks, mobile cellular networks and broadband local area networks – with potential to be deployed in the "digital dividend" bands in configurations of access and use that, however, remained unspecified.

This reserved approach on behalf of the European Commission can be justified on two grounds. First, the Commission itself chose to adopt a strategy focused on redistributing the market for electronic communications rather than redistributing the radio resource, in the aftermaths of applying prescriptive radio spectrum allocations for third generation mobile communications networks that did not replicate the market growth of GSM networks. This could explain why the European Commission advocated a high degree of flexibility in defining operational rights for specific applications or services. Second, the industry itself chose to formalise and negotiate its strategies outside the policy

[143] The Commission indicated that the UHF band (470 MHz to 862 MHz) without specifying how much of this band is considered for reorganisation or refarming (EC 2007: 9).
[144] The Commission suggested three types of networks for the UHF sub-bands: high power networks (broadcasting), medium power networks (mobile cellular) and low power networks (fixed and mobile local area networks). The Commission referred to these types of networks as "application clusters" (EC 2007: 9).

framework established around the European Commission in the EU, particularly because the digitisation and convergence agenda were deemed disruptive to established positions of rivalry and excludability in the radio resource. This could explain why the industry preferred other transnational venues such as the regional CEPT or the global ITU to negotiate the allocation of the digital dividend. The next section looks at the distribution of interest and capabilities among the established industry – broadcasting and mobile telecommunications industry – in order to explain their preference for negotiating property arrangements for the digital dividend band – particularly the 800 MHz band – outside the policy framework of the European Union.

5.1.3 The Initial Distribution of Private Interests and Private Resources

The established electronic communications industry in Europe responded differently to the potential reorganisation of the digital dividend bands, particularly the 470-862 MHz band (i.e. the UHF band). On the one hand, the broadcasting industry had an established position of reduced rivalry and effective exclusivity in the UHF band (470-862 MHz) since the Stockholm Regional Agreement on the allocation of broadcasting services in 1961. Under these conditions, the broadcasting industry supported safeguarding the radio resource for continued broadcasting services as well as maintaining traditional allocation mechanisms based on individual, exclusive use of the radio resource. On the other hand, the mobile communications industry was also in a position of reduced rivalry and effective exclusivity as a result of the creation of regional frequency pools at 900 MHz and 1.9-2.1 GHz, but were faced with two diverging market outcomes from that the same configuration of property arrangements. In the case of the 900 MHz pool for the deployment of GSM this configuration of individual exclusive rights led to high spectrum occupancy levels and successful markets whereas, in the case of the 1.9-2.1 GHz pool for the deployment of UMTS, this configuration led to low spectrum occupancy levels and slow market development. Under these conditions, the mobile communications industry proposed redistributing the radio resource between broadcasting and mobile communications networks as well as applying a more flexible approach to property arrangements in the radio resource. This section details the formation of these preferences as well as their distribution based on the technology capabilities available to the broadcasting and mobile communications industry. This distribution of interests and technology capabilities informed industry actor strategies in negotiating regional and global arrangements for the refarmed 800 MHz band.

The broadcasting industry responded with considerable reservation to the process of digitisation and, more broadly, to the convergence of the electronic communications industry. There are two explanations for this reserved approach. First, convergence was perceived as extending principles of network design in information technology and telecommunications to broadcasting services that operated under different regulatory conditions for content and services (Cullell and March 2011, Michalis 1999). In the framework for convergence, a broadcasting network would, in fact, become an access system for all digital applications and services and could potentially reduce the transmission of broadcasting content in favour of other applications.

This position explains why the broadcasting industry, and particularly the terrestrial broadcasting industry in Europe, did not kick-start the switchover soon after the adoption of the DVB standard in the mid/late 1990s[145]. Second, the broadcasting industry was aware that the switchover from analog to digital broadcasting would produce residual radio resource in their allocated frequency bands, whose keeping would have to be justified on the basis of projected demand. This reorganisation would challenge an established and exclusive industry position since the early 1960s, when the ITU Regional Radio Conference (RRC 1961) agreed a primary allocation for broadcasting services in the 47-68 MHz (Band I), 174-230 MHz (Band III - VHF) and 470-862 MHz (Band IV/V – UHF).

Consequently, the broadcasting industry across Europe preferred the venue of the European Broadcasting Union (EBU)[146] to organise a position against any immediate

[145] The DVB Consortium that promoted the DVB family of standards was formed by both established broadcasters and telecommunications manufacturers in Europe and, in fact, created the DVB standard not as a broadcasting standard (such as PAL or SECAM) but as a transport standard, as one "used generically to describe the transport of media content from one point of origin to multiple receivers – irrespective of the physical network used for this transport" (Reimers 2006: 173).

[146] The European Broadcasting Union (EBU) was founded in 1950, having as predecessor the International Broadcasting Union (1925) that set up the first regional allocations for the "European area" (revisit *Chapter 1*). EBU has a wider membership than the EU, largely mapped on the CEPT, and is a formal industry association that coordinates frequency planning and some aspects of standardisation of broadcasting services. R. Gressmann (2000), former Director of the EBU Technical Centre, noted that, whereas the international frequency plan did not always reflect the de facto reality

redistribution of the digital dividend to other electronic communications services and under more flexible property arrangements. In fact, public broadcasting operators in EBU held homogenous preferences against the redistribution of the digital dividend and delivered this position, via EBU, to the European Commission as well as to the CEPT. The latter was the preferred venue for coordination for broadcasting representatives in EBU, who chose the CEPT for its wider membership than the EU, its "proven infrastructure to arrange coordination" as well as its capability "to broker compromises needed for international planning" (EBU 2004):

> "[C]urrent EBU studies show that in the European environment, with its high population density, achieving universal national coverage with even the six multiplexes sought by most nations will require virtually the complete broadcast bands to be used solely for broadcasting. […] Providing 'universal' coverage is part of the public service mission and doing so will require adequate spectrum. […] Flexible allocations may be efficient for point to point services, but they are counterproductive for free to air broadcasting services, where receivers need to reliably and rapidly find broadcast stations" (EBU 2004).

On closer analysis, this position of the broadcasting industry in Europe reveals its initial strategy in negotiations about the digital dividend. First, the broadcasting industry did not commit to an exact residual of radio resource after the switchover[147] compared, for instance, with the public actor that estimated it to at least double the available space (EBU 2004, EC 2003). Second, the broadcasting industry justified keeping the existing radio spectrum allocations – even after the switchover – based on public service considerations of "universal coverage" rather than on considerations of existing or projected demand for two-way (i.e. interactive) multimedia services. Lastly, the industry opposed the application of flexible allocations for broadcasting services in the radio resource and advocated for "traditional allocation mechanisms" based on individual and exclusive use of frequency bands on considerations that broadcasting services require powerful stations and stable emissions (EBU 2004).

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in the different spectrum regions, "the EBU lists were generally recognised as reliable and unbiased unbiased reports of the de facto situations in the frequency bands allocated to broadcasting" in Europe (Gressmann 2000: 18).

[147] The exact position of the broadcasting industry states: "it is too early in the planning process to know what residual frequencies may or may not be available after the switchover, and hence this question cannot be answered completely at the moment" (EBU 2004).

In contrast, the mobile communications industry in Europe adopted a less homogenous but different position than the one adopted by the broadcasting industry. Overall, the mobile communications industry advocated for the redistribution of some residual radio resource to two-way electronic communications services, particularly mobile data services. However, established operators and established manufacturers in the mobile communications industry adopted relatively different positions on the exact frequency bands of the digital dividend to be redistributed for broadband services as well as on the flexibility of the property arrangements to be adopted in these bands.

First, the mobile communications industry was in overall agreement over the residual radio resource to be "free" after the digital dividend: "Digital television is approximately four times more efficient than analogue television in the broadcasting service" (ITU-R SG1 qtd in UMTS Forum 2004). Second, the mobile communications industry was in overall agreement that "it should be considered whether this spectrum [digital dividend] could be allocated to mobile services" (UMTS Forum 2004). However, whereas manufacturers seemed to be interested in the lower parts of the digital dividend (i.e below 600 MHz), operators were interested in the upper parts of the digital dividend (i.e. the 800 MHz band). The positions of established manufacturers and an established operator are provided to exemplify these differences:

> "[W]e recommend to think about identification of this spectrum for interactive services like interactive broadcast for stationary and mobile use and other individual bidirectional media communications, where spectrum will be used in two directions such as mobile telephony including high bandwidth […] interfaces, wireless LAN etc" (Siemens 2004).
>
> "An example of such a separate service would be low-cost wide area coverage fixed or mobile communications for rural area, facilitated by the better propagation characteristics of the frequencies constituting the broadcasting bands, compared to current commercial mobile communications frequency bands" (Ericsson 2004).

Established manufacturers were thus motivated to set in motion the interactive media market for mobile cellular communications, which had a slow start with the introduction of third generation mobile communications networks in the early 2000s. This is certified by the low penetration rate of third generation mobile communication systems (UMTS/W-CDMA) across Western Europe in the mid 2000s, compared with still dominant second generation systems (GSM) (*Figure 5.3*). Thus, the slow deployment of third generation systems in the higher 2GHz bands (1.9-2.1 GHz) determined manufacturers to press for deployment of these interactive systems in frequencies below 600MHz where, as Ericsson noted, the costs of setting up the physical infrastructure for these services would be lower due to the more stable penetration rate and wider coverage areas of these bands (Ericsson 2004, UMTS Forum 2004). In addition, data services – including interactive services – via mobile cellular communications networks (i.e. wide area networks) were challenged by a "newcomer" technology in the form of WLANs (i.e. local area networks such as Wi-Fi).

In fact, in the early 2000s the mobile communications industry was unsure whether WLANs providing local broadband services would become "disruptive technologies" to wide area cellular mobile networks providing lower data service rates (Weber et al 2004: 385, also see *Chapter 6*). Hence, in the mid 2000s, established manufacturers in mobile communications were looking at ways to integrate and interwork the two technologies without disrupting each other's markets[148] (Ahmavaara et al 2003). This meant that manufacturers were supporting a more "scattered" or "spread" approach to overlaying mobile communications services – such as broadband services provided by WLANs – on spectrum primarily allocated to broadcasting or mobile communications.

However, mobile communications operators took a different approach to the redistribution of the digital dividend, supporting more flexible operational rules in the radio resource while discouraging the application of a "scattered" approach to deploying wireless communications:

> "Technology and technology neutrality is in general good. However, it is important that the spectrum for certain services will not become too scattered. This is especially important for mobile services where the mobile terminals must be able to travel worldwide. […] It is important that spectrum is allocated to the market in the same way as spectrum for other public telecom services. […] If the same technology could be used for

[148] The formation of these strategies is discussed in more depth in the next case study, which looks at the creation of property arrangements in the 2.4GHz and the 5GHz frequency bands for WLANs (see Chapter 6). At this point, it is only important to know that the two technologies 3G cellular and WLANs were initially perceived and competing technologies for wireless access to broadband data services and that in 2003 the mobile cellular communications industry and the information technology industry aligned their technology preferences to interwork the two systems. The result was that 3GPP, the industry association that developed and maintained the GSM and the UMTS standards, took the initiative to develop a cellular-WLAN interworking architecture "as an add-on to the existing 3GPP cellular system specifications" (Ahmavaara et al 2003). Note that Ahmavaara et al (2003) contributed to this work on behalf of Nokia, who was one of the main promoters of this initiative and one of the founding members of the Wi-Fi Alliance that rebranded WLANs into the Wi-Fi product.

> different purposes, that will be more efficient for both operators and customers. However, it still should be needed to gather common types of technology in the same or adjacent frequency bands to avoid interference problems and fragmentation” (TeliaSonera 2004).

Mobile communications operators were most affected by the telecom crash in the early 2000s and, subsequently, were not interested in new technologies – such as WLANs – that would disrupt cellular communications networks. For this reason, they were mostly interested in the upper parts of the digital dividend – i.e. around the 800 MHz band – because this part of the dividend was directly adjacent to the 900 MHz band where GSM services were deployed and, subsequently, represented a way of enlarging the frequency pool for mobile cellular communications services without incurring additional costs from pairing fragmented allocations in the lower bands.

Overall, this configuration of economic interests and technology preferences regarding the redistribution of the digital dividend reveals the strategies of the three main interested parties in the wider electronic communications sector. First, the broadcasting industry had relatively homogenous preferences for maintaining the radio resource in their operation and for applying property arrangements based on individual and exclusive licensing. Second, the mobile communications industry had more diverse economic interests, with manufacturers supporting a greater variety of technology options (e.g. WLANs) to be deployed in a wider frequency range (e.g. lower than 600 MHz) and following more flexible allocations (e.g. overlaying WLANs on broadcasting/ telecom spectrum) than the operators who were supporting less technology variability (e.g. mostly cellular) in a lower frequency range (e.g. mostly upper dividend in 800 MHz) and with less flexibility in allocations in order to reduce fragmentation and maintain service exclusivity (e.g. no overlays). The next sections reveal the distributional effects of these conflicting interests on the creation of property arrangements in the 800 MHz frequency pool at global level. The next sections show that, by setting up voluntary collective arrangements for negotiating operational rules for future mobile communications systems, manufacturers and operators in Europe were not only able to align their preferences but also to put forward a new property arrangement in the 800 MHz band based on common exclusive property rather than individual exclusive property.

5.2 The Process of Private Rule-Making in the 800 MHz Band

The next sections follow the negotiation of new operational rules of access and use of the 800 MHz frequency band in the lead up to the digital switchover that commenced in the late 2000s in Europe (2009-2013). First, they trace negotiations in the broadcasting industry for defining operational rules for the 800 MHz frequency band, which finalised with an ITU Radio Regional Conference (RRC-06) that maintained the digital dividend bands in the operation of the broadcasting sector in Europe. Then, they trace negotiations between mobile communications operators and manufacturers, which focused on the design of a new technology system – called IMT-Advanced – which would create a flat architecture for the integration, rather than the exclusion, of previously competing technologies in mobile communications. Referred to as the fourth generation of mobile communications[149] (4G), the new IMT-Advanced system aligned the economic and technology preferences of both operators and manufacturers by proposing specifications that would maintain service exclusivity, as preferred by operators, coupled with technology flexibility, as preferred by manufacturers. This industry alignment was achieved by setting up collective arrangements in informal industry associations based on equitable participation of the two industry parties in system design, flexible consensus building on system specifications and cross-monitoring in systems development. This alignment gave the mobile communications industry considerable weight to overturn the initial assignment of the 800 MHz band to broadcasting services and to re-assign it to mobile communications systems based on IMT at the World Radiocommunication Conference of the ITU in 2007 (WRC-07).

The decision taken at WRC-07 for the 800 MHz band was novel in two ways. First, it created a global frequency pool for system specific (IMT) mobile communication services, which included the 800 MHz band as well as previous regional pools such as the 900 MHz band, essentially enlarging the global frequency pool for IMT systems. Second, by assigning this global frequency pool to IMT systems, it formalised property arrangements embedded in technical specifications for this system. Thus, rights of access to the global frequency pool were assigned exclusively to mobile communication systems. However, rights of use were not defined in relation with the adoption of a

[149] Although IMT-Advanced systems, including the most widespread specification of the systems called Long Term Evolution (LTE), are referred to as fourth generation (4G) mobile communications technology, they are not evolutionary technologies from second generation or third generation systems.

given set of technology specifications – as in the case of GSM or UMTS. Instead, operators had the flexibility to independently define the rate of use of the radio resource, by selecting from a number of mobile communication systems (or "generations") based on considerations of market demand or need. This flexibility in the use of the radio resource suited manufacturers and operators alike and led to the creation of property arrangements based on the common use of complementary systems rather than the individual use of competing systems, setting a new property regime in the 800 MHz band based on common exclusive property.

5.2.1 Negotiating Rules of Management and Exclusion

The first formal negotiations concerning the redistribution of the digital dividend bands in Europe took place, in two rounds in 2004 and, respectively, in 2006, in the ITU *Regional Radiocommunication Conference for Planning of the Digital Terrestrial Broadcasting Service in Parts of Regions 1 and 3, in the Frequency Bands 174-230 MHz and 470-862 MHz* (RRC-04 and RRC-06)[150]. The planning area of the conference was, thus, considerably larger than the European area (i.e. Regions 1 and 3 of the radio spectrum[151]) and, subsequently, the European Broadcasting Union (EBU) – as the interest association for public broadcasting operators in Europe – coordinated with the CEPT in order to represent the interests of the European broadcasting industry. As expected, the conference discussed the digital plan for the implementation of terrestrial digital broadcasting in the two bands. Concerning the redistribution of the bands during and following the digitisation process, two issues were considered. First, the adoption of the exact parameters for the digital television standard to be adopted and the exact channel assignments for digital broadcasting stations in the area covering Europe, Africa, the Middle East and the northern half of Asia (i.e. "parts of Regions 1 and 3). Second, the distribution between broadcasting services as primary services on the band and "other primary services" that could share these bands. On the first item, the

[150] In 2000, the administrations members of CEPT requested the ITU to convene a Regional Radiocommunication Conference in order to revisit the Stockholm Agreement 1961 in light of the introduction of digital broadcasting in the European Broadcasting Area, proposal accepted by the ITU in 2002. See Puigrefagut and O'Leary (2004).

[151] Region 1 and Region 3 cover over half of the global radio resource. See *Annex 1* of this thesis on the division of the world in three radio spectrum regions. Also, see T. O'Leary, E. Puigrefagut and W. Sami (2006) for an in-depth discussion of the results of the RRC-06, including a map of the planning area (2006: 21).

conference adopted the position of the broadcasting industry in Europe – EBU via CEPT – that proposed to maintain the radio spectrum allocations for primary broadcasting services and to adopt assignment parameters based on the DVB-T standard. In line with this position, the new digital plan that resulted from RRC-06 assigned over 90% of frequencies in use in Band III (174-230 MHz) to T-DAB digital radio broadcasting services and over 98% of frequencies in use in Band IV (470-862 MHz) to DBV-T television digital broadcasting services (O'Leary et al 2006: 6-9). In fact, the Vice-Chair of the CEPT WG RRC-06 Working Group, F. Rancy (2005) argued in favour of keeping the allocations for broadcasting services on the basis that it was "premature to make a decisions regarding IMT-2000 in Band IV/V until the outcome of RRC-06 is known" (Rancy 2005).

The second item – i.e. the co-existence of broadcasting with other primary services – was more controversial. As discussed above, historically, broadcasting services had de facto exclusivity in Bands IV and V, although, de jure, their primary status did not determine their exclusive use of the band. In this circumstance, digital broadcasting services could share the resource with other primary services as long as they were granted access and as long as they were not interfering with existing broadcasting services. On this item, CEPT administrations took a middle ground approach between the broadcasting industry and the mobile communications industry in Europe. On the one hand, the RRC-06 Plan would not redistribute any original allocations to other services, as preferred by the broadcasting industry. On the other hand, the RRC-06 Plan would allow other terrestrial applications to share the two bands as long as "such use does not cause more interference than would be caused by the digital entry in the Plan", as preferred by some of the mobile communications industry, particularly manufacturers (O'Leary et al 2006: 15). As EBU members O'Leary, Puigrefagut and Sami (2006) noted, this so-called "envelope concept" was not preferred by broadcasters, particularly non-European broadcasters present at the conference, because it would essentially "open the plan to non-broadcasting services" (O'Leary et al 2006: 16). In reality, mobile communications operators did not prefer this type of flexible sharing either because it had the potential to change what was, de facto, exclusive use of the radio resource on principles of non-interference with the primary service. The position of the telecommunications operator TeliaSonera, in the context of the digital dividend, is a good example to confirm this expectation:

> "If a certain part of the spectrum is reserved to broadcasting only and assigned according to broadcasting regulation (as opposed to telecom regulation) that part should not be able to use for telecom purposes" (TeliaSonera 2004).

In this circumstance, RRC-06 arrived to what O'Leary, Puigrefagut and Sami (2006) call "a compromise package", by which other digital services could be added to the RRC-06 Plan even if they did not have the technical characteristics of those specified in the Plan but as long as they had primary status in conformity with the ITU Radio Regulations (Art 5.1.3 RRC-06). EBU members O'Leary, Puigrefagut and Sami (2006) break down the essence of this "compromise":

> "Broadcasters were less unhappy with that text [Art 5.1.3 RRC-06] as it is more restrictive than the initial proposal from CEPT. Before using a digital entry in the Plan for a non-broadcasting terrestrial application, the corresponding service must be allocated as a primary service in the relevant frequency band in the ITU Radio Regulations (RR). The frequency allocations can only be modified by an ITU World Radiocommunications Conference (WRC)" (O'Leary et al 2006: 16).

There is no doubt that this compromise was most favourable for the broadcasting industry because it maintained de facto exclusivity for digital services in the exact frequency pool used for analogue broadcasting services. The results of the RRC-06 were, however, least favourable for the mobile communications industry, manufacturers and operators alike. For mobile communications manufacturers, the RRC-06 would remove the flexibility to overlay non-primary services to the broadcasting bands unless those services gained primary status at the global level – i.e. in WRC – where economic interests and the distribution of technology capabilities would be considerably more diversified than at regional level. For mobile communications operators, the RRC-06 would remove the certainty of de facto service exclusivity associated with the primary status granted, traditionally, to operators of public services in telecommunications and broadcasting. In this context, a middle ground option for the industry was to develop a mobile communications system that would provide the technological flexibility preferred by manufacturers together with the service exclusivity preferred by operators and to promote it for primary status in the digital dividend bands at international level, prior to the World Radiocommunications Conference scheduled for 2007 (WRC-07). The mobile communications industry achieved this collective arrangement in three stages that took place from 2004, when negotiations started in RRC-04/06, to 2007, when negotiations started in WRC-07. The three stages correspond to the establishment of rules of equitable participation of competitors in system design, rules of flexible consensus building in informal industry associations and rules of cross-monitoring in system development achieved between informal industry associations. This type of collective choice arrangement mitigated the effects of heterogeneity of interests and technology capabilities in the industry and led to the collective promotion of the IMT-Advanced mobile communications systems – based on technological flexibility combined with service exclusivity – for allocation in the 800 MHz digital dividend band at WRC-07.

The first step in the establishment of collective choice arrangements towards IMT-Advanced was made by mobile communications manufacturers, which set up an informal industry association – in the form of the Wireless World Research Forum (WWRF) - in August 2001 in order to develop a flexible core network that would integrate, rather than exclude, existing second and third generation systems. There are two main economic considerations for the decision of the manufacturing industry to set up the research forum.

First, and as described in the previous sections, the market for mobile cellular communications was slowing down due to limited deployment of third generation mobile communications systems as well as to potential competition from local area networks (WLANs) for wireless data services.

Second, the 3G Partnership Project (3GPP) was slowly changing status from an informal strategic partnership into a formal standards development and standards maintenance association, following the transfer of second generation (GSM, EDGE) and third generation (UMTS) standardisation responsibilities from ETSI. In fact, in the early 2000s, the 3GPP became a meta-standardisation body comprising the majority of regional standardisation institutes (e.g. ETSI, ARIB, TTC) and industry associations (GSMA, UMTS Forum) that adopted second or third generation systems based on the GSM core network (*Table 5.2*).

Table 5.2 3GPP Membership by No of Individual Members and Respective Organisational Partners

Organisational Partner	**No of Individual Members 2000**	**No of Individual Members 2013**
ETSI	173 (61%)	291 (76%)
ARIB	37 (13%)	25 (6.5%)
TTC	18 (6%)	9 (2%)
T1 *(later the entire **ATIS**)*	22 (8%)	30 (8%)
TTA	25 (9%)	13 (3.5%)
CWTS/CCSA	9 (3%)	23 (6%)
Total	284	381

Source: Based on 3GPP (www.3gpp.com) and Rosenbrock (2002: 241)

The state of the mobile cellular communications market, coupled with the formalisation of decision-making in 3GPP, determined leading manufacturers in Europe – Alcatel, Ericsson, Motorola and Siemens[152] – to set up an industry association that would coordinate research for a new core network, which would integrate existing second and third generation mobile communications systems, as well as research for a new radio access network that would provide increased data transfer rates. Thus, the Wireless World Research Forum (WWRF) was set up in 2001 with the aim to coordinate early research for complementary radio access networks integrated into a horizontal core network that would operate on principles of technology inclusion rather than technology exclusion of proprietary and competing systems. W. Mohr, the Chairman of the Wireless World Initiative (WWI), noted that the aim of the forum was to identify and develop global mobile communications systems beyond the IMT-2000 family of standards for third generation mobile communications, to integrate them in a flexible core infrastructure and to feed them through further development and standardisation

[152] As of January 2014, the WWRF has a membership of approximately one hundred members, comprising of manufacturers and specialist research centers.

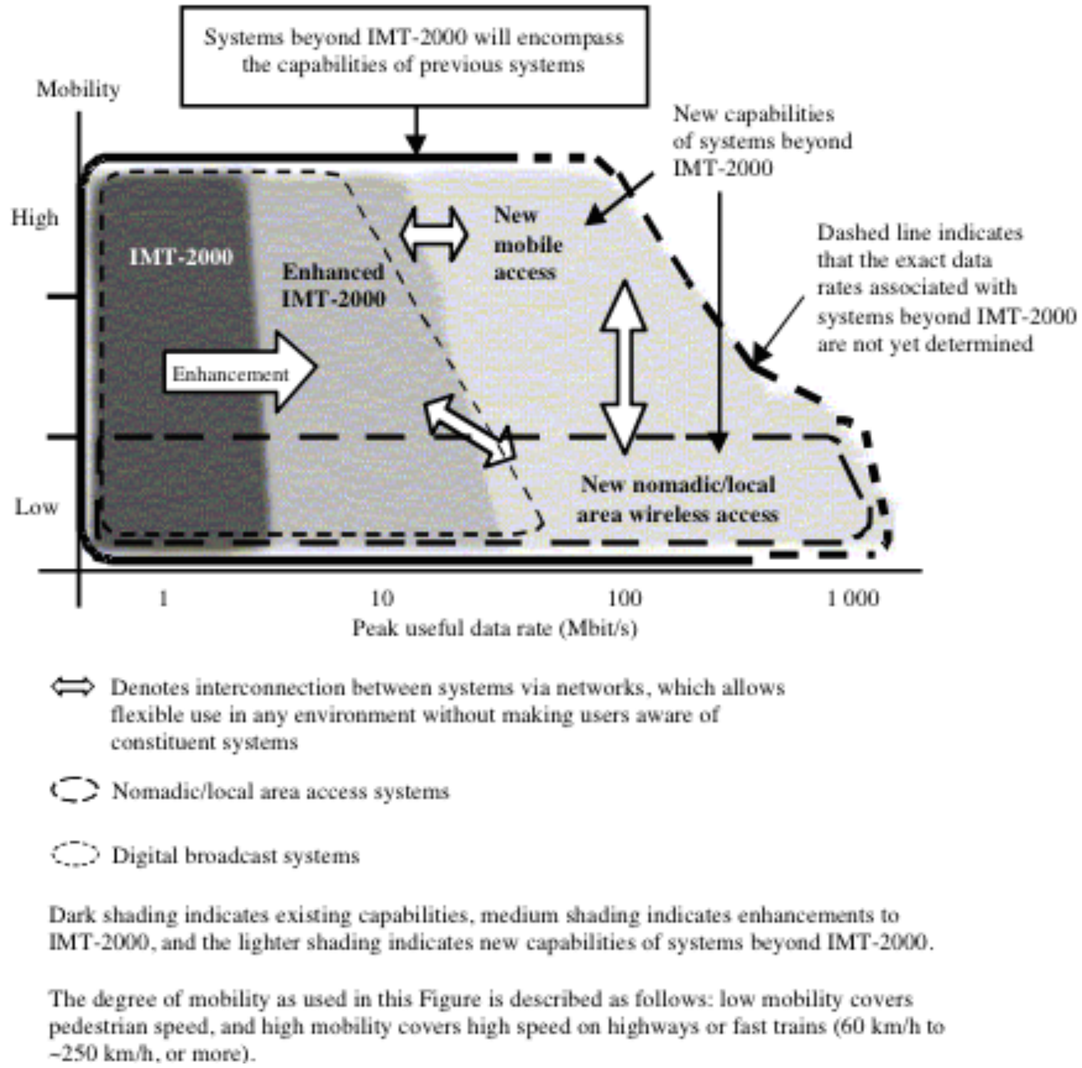
channels such as European Research Programmes (WINNER), ETSI, 3GPP and the ITU (Mohr 2003, Mohr 2006)[153].

There are two fundamental differences between this approach and previous collaborative approaches conducted by the mobile communications industry for second and third generation communications systems. First, principles of collaboration – rather than competition – are moved from late stages in the system development process (i.e. standardisation as seen in ETSI) to the very early stages in the development process (i.e. research design and research principles). This is a clear departure from previous cases, such as GSM or UMTS, when the manufacturing industry developed proprietary technologies independently in the first instance and collaborated in the later stages, during the standardisation process, in order to ensure that property arrangements in the radio resource and in the communications market are structured around their proprietary technologies. Second, competition between proprietary technologies for the same "generation" of communications system was replaced with co-existence of the different standards corresponding to a single generation. *Figure 5.3* illustrates the "vision" of mobile communications manufacturers for the integration of mobile cellular communications and wireless communications technologies providing different data transfer rates (horizontal axis) with different levels of mobility (vertical axis).

Nonetheless, this collaborative approach based on the participation of competing technologies in all stages of the development process is grounded in market growth considerations (short and long-term) as well as in redistributive resource considerations. On the one hand, integrating competing standards of radio access networks (e.g. GSM, UMTS, cdma2000) on a single core network would allow flexibility to deploy a particular generation of communication systems (i.e. second, third, fourth) based on demand for added value services, without having to invest in core network evolution for a particular variant of radio access network.

[153] In a presentation to the ITU, W. Mohr noted that "due to long cycles for research, standardisation and frequency assignment, research on systems beyond IMT-2000 has to start now" (Mohr 2002).

Figure 5.3 Illustration of Capabilities of IMT-2000 and Systems Beyond IMT-2000



Source: ITU-R (2003: 9), Permission to reproduce granted by ITU Legal Affairs Unit

This was perceived as reverting the market trend following the introduction of third generation mobile communications systems across Europe and worldwide. It is exemplified by the case of W-CDMA (UMTS) and cdma2000, which were competing standards for radio access networks of third generation mobile communications systems[154] and were integrated in the new horizontal architecture of the core network for "systems beyond ITM-2000" (i.e. IMT-Advanced), soon after Qualcomm joined the WWRF (Beming et al 2007). Most importantly, this integrated network would kick-start the market by giving operators the flexibility to maintain services for as long as markets were profitable (as in the case of second generation GSM) and to gradually phase them

[154] Revisit the previous chapter (*Chapter 4*) for a discussion on the competition between W-CDMA, promoted by established manufacturers in Europe and Japan, and cdma2000, promoted by established manufacturers in the United States.

out without having to purchase duplicate rights of access and use in new frequency bands (as in the case of third generation UMTS or cdma2000). On the other hand, the choice of core network – an "all IP-based" core network – would allow the co-existence of wide area networks (i.e. cellular mobile networks) with competing local area networks (i.e. LANs) that were providing high speed data rates with relatively lower mobility (Mohr 2002, Abramowicz et al 2004).

This decision to integrate the two technologies was informed by considerations that the mobile cellular communications market was slowing down compared with IP-based services provided by wired and wireless local area network[155]. In fact, by maintaining its status as an informal research association of mobile communications developers, the WWRF provided considerably more flexibility in consensus building than formal standardisation associations such as ETSI or 3GPP. This constitutes the second step in the development of collective choice arrangements for managing future technology systems based on the radio resource. Once developers with considerable patent portfolios in competing technologies – i.e. W-CDMA (e.g. Ericsson, Siemens) and CDMA (e.g. Qualcomm) – joined the WWRF, they agreed to put forward a new "all IP based" core network that would support any of these competing radio access systems. Thus, the "all IP based" network could equally support evolutions from operators that deployed W-CDMA access network (as promoted by 3GPP) or CDMA access network (as promoted by 3GPP2), without having to tie their infrastructure investments in prescriptive radio access systems (revisit *Chapter 4*). This early informal alignment paved the way for the two formal associations 3GPP and 3GPP2 to agree, in 2007, network optimisation paths for GSM/W-CDMA and CDMA to evolve towards a fourth generation radio access technology called Long Term Evolution (LTE) and a new core network named System Architecture Evolution (SAE) developed by 3GPP but based on the all-IP system designed collectively in the WWRF.

In this context, between 2001 and 2003, WWRF members made several proposals to the ITU for "systems beyond IMT-2000" based on the specifications listed in *Figure 5.4*. Because the ITU Radiocommunication Sector (ITU-R) was the "keeper" of the IMT-2000 family of standards for third generation mobile communications systems, the

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[155] The next chapter (*Chapter 6*) looks at the development of WLANs. It shows that, in 2003, 3GPP took an initiative to "develop a cellular-WLAN interworking architecture as an add-on to the existing 3GPP cellular system specification" (Ahmavaara et al 2003: 74).

mobile communications industry used this international venue to put forward evolutions to IMT-2000 systems. Although the ITU-R did not have authority to produce technical specifications, it did have authority to produce recommendations for future systems, bringing considerations of radio spectrum need derived from new technological development directly at the international level, where the status of communications services – i.e. primary, secondary, etc – was negotiated. Subsequently, in 2003, ITU-R published *Recommendation M1645 for the Future Development of IMT-2000 and Systems Beyond IMT-2000*, making clear reference to the flat, integrated architecture of mobile communications systems developed in the WWRF:

> "Systems beyond IMT-2000 will be realised by functional fusion of existing, enhanced and newly developed elements of IMT-2000, nomadic wireless access systems and other wireless systems with high commonality and seamless interworking" (ITU-R 2003).

Thus, the approach put forward by the WWRF differed from previous industry coordination strategies. Instead of coordinating standards based on competing patented technologies in formal industry associations, established developers engaged in early research coordination based on flexible network architecture, aimed at kick-starting the cellular mobile communications market after the telecommunications crash in the early 2000s. However, the technological flexibility proposed by the WWRF differed from previous methods of prescribing access to the radio resource based on technological excludability (i.e. GSM or UMTS). As such, the technological configuration of this new system would fundamentally challenge established rules of access and use of the radio resource for mobile communications. In addition, by channelling it through to the international level in the ITU, mobile communications developers made a direct case for the redistribution of services in the global radio resource where primary service allocations were considered.

This flexible approach to designing the system architecture in WWRF received a more defined response from established communications operators than the previous case studies, which look at the standardisation of GSM for the 900 MHz band and UMT for the 1.9-2.1 GHz bands. This makes the third and final stage in the creation of collective choice arrangements for managing systems to be potentially deployed in the digital dividend bands. Similar to the initial strategy adopted by manufacturers, mobile communications operators with established markets at international level agreed to set up the Next Generation Mobile Network Alliance (NGMN), in March 2006, in order to provide network requirements against the specifications agreed upon by developers. Similar to the WWRF, the NGMN was an informal industry association representing operators with appropriation interests in global frequency pools where IMT-2000 systems were already deployed: China Mobile, France Telecom (Orange), T-Mobile, Vodafone, Sprint, NTT DoCoMo and KPN.

As ENP Newswire (2008) noted, members of the NGMN Alliance[156] "represented more than half of all mobile phone users worldwide", confirming the economic interests of these operators in the development and allocation of evolved mobile communications systems. Thus, in a first White Paper produced in 2006, the NGMN Alliance sets out a procedure for evaluating system parameters that developers had to follow in order receive contracts for evolved networks (NGMN 2006). This level of cross-monitoring in system development had not been reached in previous negotiations over technology specifications – GSM or UMTS – where operators had relatively weak positions throughout the development process. Accordingly, the NGMN specified that flexibility over the choice of technology to be adopted for next generation networks had to rest with operators rather than with manufacturers. Implicitly, all IP based next generation networks had to provide the flexibility to phase in and out of different radio access network – i.e. GSM, W-CDMA, CDMA – without having to reinvest in infrastructure developments:

> "The not so distant future is a multi-modal one, in which users are agnostic to access and expect ubiquity of service coverage, security and immediate satisfaction. […] The generic NGMN systems [is expected to] co-exist with the classical circuit-switched segment of today's mobile networks such as 2G/3G solutions, which in time will phase out, as packet-switched [IP based] systems pick up legacy roamers into NGMN networks transparently" (NGMN 2006: 13, 22).

Thus, the strategy of the NGMN Alliance differed substantially from previous development cycles, where rules of access and use of the radio resource were determined by technology excludability in negotiations among established manufacturers (revisit *Chapter 3* and *Chapter 4*). Following these requirements for technology flexibility of co-existing systems, the NGMN Alliance proposed the international allocation – on a primary or co-primary basis – of additional space in the upper limit of the digital dividend bands – otherwise allocated to broadcasting services

[156] By 2008, the NGMN Alliance had over 50 member operators, deploying different generation systems with competing technology specifications.

– to IMT-Advanced Systems. This position, expressed in an NGMN White Paper (2007), was put forward only a few months prior to the World Radiocommunications Conference of 2007 (WRC-07), opening the possibility to change the regional allocation of the digital dividend bands, made for primary broadcasting services in the RRC-06 Plan, to global allocation for primary mobile communications services:

> "The most suitable spectrum for wide-area coverage of the next generation of mobile networks is within the UHF band (i.e. 470-806-862 MHz) which is currently used for terrestrial broadcasting in many countries. With the introduction of more spectrally efficient digital terrestrial TV, parts of this band will become available for alternative use ("digital dividend"). As claimed previously, the NGMN alliance feels that the most benefits in terms of economy and society in usage of spectrum are derived by making a significant portion of the UHF band between 470 and 806/862 MHz available to mobile broadband communications as soon as such spectrum can be made available (in some countries already by 2010) […]" (NGMN 2007: 17).

Thus, the NGMN Alliance put forward a proposal for setting rules of access for the digital dividend bands – comprising the 800 MHz band – based on principles of service exclusivity at international level. The position of the NGMN Alliance represented a considerable counterweight to the broadcasting industry that had just secured de facto service exclusivity in the RRC-06. In addition, the position of the NGMN Alliance was in line with Recommendations M1645 (2003) and M2078 (2006) of the ITU-R, which, based on industry estimates, proposed the total spectrum bandwidth requirements for IMT-2000 and IMT-Advanced systems to be 1,280 MHz to the year 2020. Also, the position of the NGMN Alliance confirmed a preference for setting rules of use of digital dividend bands based on principles of technology flexibility – rather than technology exclusivity – in line with the preference of developers in the WWRF.

In fact, in 2007, only a few months prior to the WRC-07, a group of key manufacturers in the WWRF – Alcatel-Lucent, Ericsson, Nokia and Nokia Siemens Networks – together with a group of key operators in the NGMN Alliance – Orange (France Telecom), T-Mobile, Vodafone and Nortel – set up the Long Term Evolution/ System Architecture Evolution Alliance (LTE/SAE Alliance) in order to conduct a trial initiative of the new network for IMT-Advanced following specifications agreed by the WWRF, developed jointly by 3GPP and 3GPP2 and expected to be tried against the network requirements established by the NGMN. The design of the network put forward by the LTE/SAE Trial Initiative represented the alignment of the otherwise diverse preferences of the mobile communications industry for a system requiring common rules of use of the radio resource based on technology flexibility combined with exclusive rules of access of the radio resource based on primary service allocations to mobile communications systems in global radio frequency pools. The next sections show how the mobile communications industry negotiated their preference for the configuration of rules of access and rules of use of the digital dividend bands – particularly the 800 MHz band – at the WRC-07, following the stages by which this configuration of property arrangements was pushed through the policy process of the ITU.

5.2.2 Negotiating Rules of Access

The WRC-07 took place from October to November 2007. The few months prior to the conference were essential in changing the rules of access for the 800 MHz band, which forms the upper part of the UHF band considered for the digital dividend. Prior to the conference, the broadcasting industry and the mobile communications industry had different positions regarding the redistribution of the digital dividend bands and organised differently to achieve their preferred configuration of rivalry and excludability in the bands. On the one hand, the broadcasting industry organised in the European Broadcasting Union (EBU), a formal interest association with established cooperation mechanisms with the CEPT, which helped achieve the result of the RRC-06 in favour of maintaining individual rights of use and exclusive rights of access for the broadcasting industry in the VHF (174-230 MHz) and UHF (470-862 MHz) bands. Because regional allocation agreements for the broadcasting industry – the first commercial industry to utilise radio waves for wireless communications – were rarely overturned at the international level, and because the new Regional Radiocommunication Conference for digital broadcasting (RRC-06) had been approved only one year prior to the World Radiocommunication Conference (WRC-07), the broadcasting industry did not redefine their position and did not organise outside the established route of the broadcasting union (EBU) and the regional administrative group (CEPT). In this context, the official position of EBU prior to the WRC-07 remained that any primary or co-primary allocations to the digital dividend bands should be postponed for a later international conference:

> "From a technical point of view, the propagation characteristics of the UHF band […] can be best exploited when a large area is covered with high power signals (typically used by broadcasting and broadcasting-like applications, one-to-many). If the same is done by cellular networks (typically one-to-one) to cover a reduced number of users this could result in a less efficient use of spectrum. […] The introduction of other services in the broadcasting bands should be done in such a way that no interference is caused to broadcasting services which already exist or which were planned at RRC-06" (EBU 2006).

In contrast, the mobile communications industry represented in the WWRF and the NGMN set up a new and informal industry group with the purpose to deliver the position of the industry on Agenda Item 1.4 in preparation of the WRC-07, which asked delegates "to consider frequency-related matters for the future development of IMT-2000 and systems beyond IMT-2000" (Agenda Item 1.4, WRC-03). The new industry group, called Mobile Industry Backing Terrestrial Spectrum for IMT (MIB) was set up in January 2007, only a few months prior to the WRC-07. It had a small membership of operators and developers - Alcatel-Lucent, Ericsson, Fujitsu, Huawei, Motorola, NEC, Nokia, Nortel, Panasonic, Qualcomm, Samsung, Siemens and ZTE - with presence in international markets and with an economic interest in the harmonised allocation of additional frequencies for IMT systems in bands adjacent or complementary to existing IMT allocations (i.e. 900MHz for GSM, 1.9-2.1 for UMTS). In addition, MIB recognised collaborations with formal industry associations such as the UMTS Forum backing GSM/UMTS networks and the CDMA Development Group backing CDMA networks, which indicates developers' alignment on technology flexibility, rather than exclusivity, as a guiding rule for using the radio resource. As J. Costa (2007), the MIB Coordinator, noted, the purpose of MIB was to deliver a detailed position of the mobile communications industry on the need for IMT systems (IMT 2000 or Advanced) in line with measurements conducted, negotiated and proposed by the industry in ITU-R, i.e. approximately 1,280 MHz additional spectrum for IMT systems by 2020[157] (ITU-R M2078). For the most part of 2007, and in preparation for the WRC-07, MIB organised

[157] As detailed above, considerations of spectrum need for IMT systems had been negotiated between WRC-03, when no new allocations to mobile communications services were made, and WRC-07, especially in ITU-R. The figure of 1,280 MHz additional spectrum for IMT systems by 2020 was derived from industry specifications that the new fourth generation radio access network would provide: a) up to 100Mb/s in full mobility in the wide area (cellular) and b) up to 1GB/s in low mobility in the local area (WLANs) (ITU-R M1645). In this context, spectrum allocations for IMT had to allow considerable flexibility for data application with higher transfer rates to operate, keeping the expected quality of service.

several seminars and presentations to the regional radio spectrum coordination bodies, such as CEPT in Europe and CITEL in the Americas, whose responsibility was to coordinate the positions of national administrations on the final distribution of the radio resource. *Table 5.3* reveals a region-by-region proposal on additional spectrum need for mobile communication systems put forward by MIB prior to the WRC-07.

Most importantly, these spectrum estimates were based on market forecasts for IMT-2000 and IMT-Advanced systems, rather than for mobile communications systems in general. This strategy meant that, rather than proposing primary allocations to generic services such as mobile, broadcasting or aeronautical, MIB proposed that any international allocations would be made specifically to IMT system rather than, broadly, to mobile communications services. This proposal would alter the fundamental principles of defining access onto global frequency pools, by limiting the principles for granting de facto exclusivity in the designated radio resource:

> "A MIB objective for WRC-07 is that, not only should sufficient spectrum be allocated to the mobile radiocommunication service, but also that it be identified for IMT in order to facilitate economies of scale and global roaming of mobile stations" (Costa 2007: 10).

Table 5.3 MIB Estimates of Additional Spectrum by Selected ITU Radio Sub-Regions, 2007

ITU Region	Regional Coordinating Body	Additional IMT Spectrum	Existing IMT-2000 Spectrum
Region 1	European Conference of Postal and Telecommunications Administrations (CEPT)	695MHz – low market 1135MHz – high market	585MHz
Region 2	Inter-American Telecommunications Commission (CITEL)	721MHz – low market 1161MHz – high market	559MHz
Region 3	Asia-Pacific Telecommunications (APT)	531MHz - low market 971MHz – high market	749MHz

Source: MIB (2007)

Based on the distribution of the radio resource showed in *Table 5.3*, MIB estimated that "existing spectrum bands will not be sufficient to carry the predicted traffic for IMT services after the year 2015"[158] (MIB 2007: 14) and recommended seven candidate bands for additional allocations of IMT at WRC-07, which were included for consideration at the WRC-07 Conference Preparatory Meetings (ITU 2007).

Table 5.4 gives a summary of the advantages and disadvantages for each of the seven candidate bands, as presented in the WRC-07 Conference Preparatory Meetings (ITU-R 2007: 33-37).

Table 5.4 List of Additional Candidate Bands for IMT Systems, Main Advantages and Disadvantages

Candidate Bands for IMT Systems	**Advantages**	**Disadvantages**
410-430 MHz 450-470 MHz	Better propagation characteristics than higher bands Very good for low population density areas	Heavily used for public safety and disaster relief
470-806/862 MHz	Better propagation characteristics than higher bands Close to other bands identified for IMT-2000, may result in reduced complexity of equipment	Co-existence of cellular stations with high power/high site broadcasting stations may result in interference
2,300-2,400 MHz	Near already identified IMT-2000 bands	In use for aeronautical, satellite and non-mobile broadband in some regions
2,700-2,900	Near already identified IMT-2000 bands	Allocated on a primary basis for aeronautical services, a safety of life service
3,400-4,200	Good for IMT-Advanced systems requiring wideband services, convergence of cellular and broadband wireless access systems	Allocated to fixed and fixed satellite services
4,400-4,990	Good for IMT-Advanced system	Intended to preserve orbit/spectrum resource for future use, on an equitable basis

Source: ITU-R (2007)

Of all the candidate bands, the most controversial at the time was the digital switchover bands between 470 MHz and 862 MHz. As identified in *Table 5.3*, their upper limit was adjacent to a band already identified for IMT (i.e. 900 MHz band), which, if extended in the lower 800 MHz band, would enlarge the operating frequency pool while minimising investments in interoperable equipment and infrastructure. In addition, the upper limit of the digital switchover band in Region 1 (Europe and Africa) and Region 3 (Asia) was already utilised for mobile communication services in Region 2 (Americas), giving the opportunity to harmonise a considerable portion of high value radio spectrum across the world.

[158] On the issue of timing, J. Costa (2007) added "from the time spectrum is allocated or identified at a conference, it may take up to 10 years to make it available to users. For that reason, it is important that spectrum be allocated or identified well in advance of when it will be needed" (Costa 2007: 10).

However, an allocation of the entire UHF band (470-862 MHz) to mobile communications on a primary or co-primary basis was unacceptable for the broadcasting industry at WRC-07. Thus, the issue of timing was raised, with the mobile communications industry pressing for immediate allocations and the broadcasting industry advocating a progressive approach to redistributions in the UHF bands. The CEPT took, once again, a middle ground approach by expressing agreement with the spectrum need estimates put forward by the mobile communications industry, as per MIB and ITU-R M2078, yet proposing that a decision for their allocation be postponed to WRC-11 (OFCOM 2007: para 1.6).

A final compromise between the two industries was reached at WRC-07. The UHF band (470-862 MHz) in Region 1 (Europe) was to be divided in several sub-bands, whose allocation would be discussed, progressively, at WRCs. Thus, at WRC-07, the upper limit of the 800 MHz band – which is now known as the first digital dividend – would be allocated on a co-primary basis[159] to IMT mobile communications systems. The allocation was made in Resolution 224 (WRC-07), which, in effect, created a global frequency pool for IMT systems at 800 MHz, overturning the regional allocations in favour of broadcasting services achieved at RRC-07:

> "Administrations which are implementing, or planning to implement IMT, should consider the use of bands identified for IMT below 1GHz and the possibility of cellular-based mobile networks' evolution to IMT, in the frequency bands identified in Nos 5.286AA [450-470MHz] and 5.317A [698-960MHz in Region 2 and 790-960MHz in Regions 1 and 3] based on user demand and other considerations" (para 1, Resolution 224, ITU 2007).

The WRC-07 concluded with several other allocations for IMT systems in globally harmonised frequency pools at 450 MHz, 2.3-2.4 GHz and 3.4-3.6 GHz (*Table 5.3*). However, the 800 MHz band is a strong example of the impact of industry associations on the redistribution of rights of access and use in a frequency pool already populated

[159] There is an obvious debate about the level of de facto exclusivity granted by an international allocation on a co-primary basis. Services allocated on a primary basis have high emissions and, at least at the current level of technology advancement, do not always co-exist well. In the case of the 800 MHz band, the allocation on a co-primary basis for mobile communications services carried high levels of de facto service exclusivity. This is reflected in Resolution 226 of the WRC-07 (ITU 2007), which recognised that "after analogue to digital television switchover, some administrators may decide *to use all or parts of the band 698-806/862 MHz f*or other services to which the band is allocated on a primary basis, in particular the mobile service for the implementation of IMT, while in other countries the broadcasting service will continue to operate in that band" (para j, Resolution 226, WRC-07).

by other interests. Of crucial importance here is the way that, by creating several layers of representation, the mobile communications industry was able to ensure primary allocation of their services on a band that had just been reallocated for other uses. It also shows that rules of access were fundamentally informed by the IMT, creating exclusivity by specific service at the ITU level.

5.2.3 Negotiating Rules of Use

The main rules of use to the radio spectrum resource were negotiated, through system development and specifications, between the NGMN Alliance and the LTE/SAE Alliance from 2006 to 2008. The position of the NGMN Alliances is essential in this process because, in contrast with the previous case studies, it allowed operators of mobile communications the ability to be represented in system development from an early stage. This was achieved through the creation of system guidelines and trials against which candidate technologies were measured. Entitled "Proof of Concept", these guidelines represented measures against which manufacturers designed and updated their core and radio access networks (NGMN 2007). As Robson noted, these "proof points" acted as "an industry-wide check" to ensure that the new systems met the NGMT Alliance requirements,

> "[…] particularly that the system has to be at least as good as the previous generation, but at significant lower cost per bit and with higher data rates and lower latency that would give consumers an experience similar to fixed broadband" (Robson 2009: 83).

In June 2008, the LTE/SAE system was selected as the winning candidate[160] for next generation networks backed by NGMN. The main consideration for choosing LTE/SAE was its flat network architecture, which resulted in a common core for all access technologies developed by 3GPP and by 3GPP2, including the LTE access technology designed the meet the system recommendations of ITU-R M.1654. This was particularly important for mobile operators because integration of LTE with GSM, WCDMA, cdma2000 and HSPA meant that operators could phasing in and out

[160] The other two candidate systems were UMB produced by Sprint, and WiMAX produced by the IEEE, but they were technologies for local wireless communications rather than for wide area communications put forward by the telecommunications industry. However, the main reason for selecting LTE/SAE was that it had a new radio access system (LTE) backed by an evolved core network, which essentially integrated, rather than excluded, previous technology generations.

of generations of mobile communications services without disrupting economies of scale already created by these technologies by the intervention of a new technology. As Robson (2009) noted, this type of integrated network configuration maintained "national coverage and global roaming from day one", a feature that was specifically attractive for mobile operators (Robson 2009: 83). Thus, this approach to network design relied on the flexible allocation of the radio resource used for IMT systems, so that operators could phase in and out of mobile communication services of different generations without having to duplicate services, invest in new physical infrastructure or to purchase licenses in new spectrum allocations. Having outlined this new configuration of operational rules in the 800 MHz band, the next section discusses the relationship between the organisation of industry actors presented above and property arrangements that resulted from this organisation of private actors.

5.3 The Impact of Private Association on the Choice of Property System

This section highlights some of the differences in the organisation of the broadcasting and the mobile communications industry for the definition of collective arrangements in the 800 MHz band, paying particular attention to their strategies aimed at accommodating diversity of interests and diversity of technology capabilities. The section shows that, in contrast with the formal organisation of broadcasting services around established policy venues – i.e. EBU-CEPT, the mobile communications industry organised in information venues – i.e. WWRF, NGMN Alliance – from an early stage into the development process. As the previous sections reveal, this type of organisation allowed for informal consensus building between system developers on the one hand, and between system developers and manufacturers on the other hand, arriving at a gradual alignment of preferences between the two industry groups in the mobile communications industry. This gradual alignment gave the communications industry considerable weight to overturn the allocation of the 800 MHz band from broadcasting services at regional level to mobile communications based on IMT systems at global level. Also, this gradual alignment facilitated the creation of different operational rules than witnessed in the previous two case studies. On the one hand, rules of use were no longer defined in relation with the adoption of a single set of technical specifications giving more flexibility of use to operators. On the other hand, rules of access were strictly defined in relation with exclusivity – i.e. mobile communication services, giving certainty to both mobile operators and system developers.

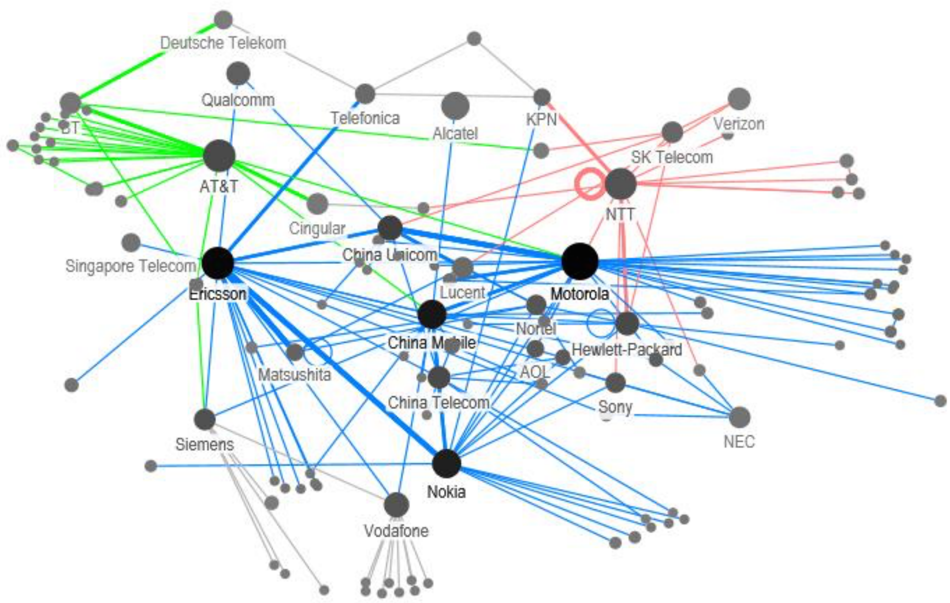
5.3.1 The Nature of Private Association

At the start of the 2000s, when policies for the digitisation of broadcasting services were being considered across developed broadcasting and telecommunications markets, the broadcasting industry made use of its traditional channels and policy venues to maintain the allocation of the VHF (174-230 MHz) and UHF (470-862 MHz) in use for broadcasting services. Because their allocation and technology preferences were relatively homogenous across the CEPT area, they negotiated a common position via EBU and the CEPT, leading to the reallocation of digital broadcasting services to the same frequency bands at the ITU Regional Conference RRC-06. However, the broadcasting industry did not clearly specify the need basis for this reallocation, in conditions when, throughout digitisation, the radio resource is used more efficiently and, subsequently, more emissions can be fitted, without interference, in a given band.

The mobile communications industry, however, took a different approach to their organisation. The slow development of the mobile communications market for third generation systems pushed industry manufacturers to a common understanding of interests prior to investments in developing and testing competing technologies. This was the aim of the Wireless World Research Forum (WWRF), an informal industry association established with the aim to align the diverse preferences of manufacturers prior to the development of competing technology systems and prior to decision-making on standards in formal industry associations such as ETSI. As discussed in the previous sections, the aim of established developers in the electronic communications market was to put forward an integrated mobile communications system that would provide flexibility for phasing out of existing services and into new services, without asking mobile communications operators to invest in new or evolved infrastructures for every change in system generation.

This position is certified by the intensity of strategic partnerships in the mobile communications industry prior and post WRC-07. Taken comparatively, *Figure 5.4* and *Figure 5.5* reveal important considerations about the global dynamics in the mobile communications industry. On the one hand, *Figure 5.4* presents a very dynamic market in terms of industry activity in strategic alliances based on technology transfers before 2005. The network representation confirms the continued nodal role of manufacturers such as Motorola, Ericsson and Nokia, in terms of the number of exchanges in the network (i.e. degree centrality and n terms of the influence in the network (i.e. eigenvector centrality) (*Table 5.5*). The comparative networks metrics in *Table 5.5* confirm the central position of developers in the first half of the 2000s, followed by the central position of operators in the second half of the 2000s.

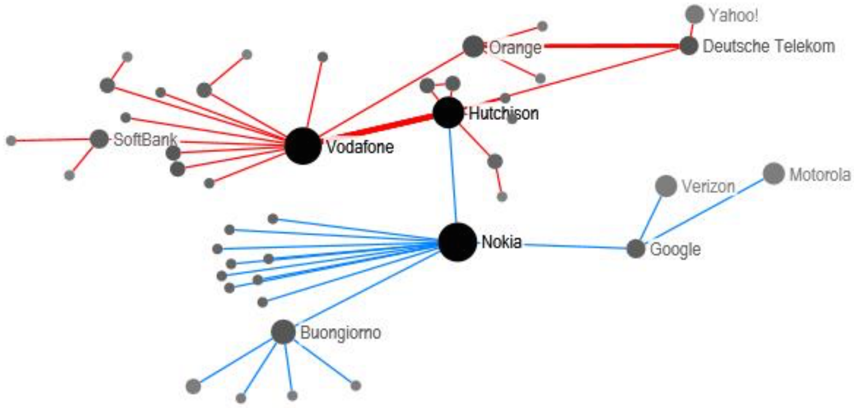
Figure 5.4 Network Visualisation of Technology Transfers, Global Strategic Alliances, Jan 2000 - Dec 2004



Source: Based on Thompson Reuters, SDC Platinum Database, Accessed Dec 2013

The visual representation in *Figure 5.5* also confirms the centrality of mobile communications operators and founders of the NGMN Alliance in the second half of the 2000s.

Figure 5.5 Network Visualisation of Technology Transfers, Global Strategic Alliances, Jan 2005 - Dec 2009



Source: Based on Thompson Reuters, SDC Platinum Database, Accessed Dec 2013

Table 5.5 Network Analysis Metrics, Global Strategic Alliances

Measures	**Network Analysis of Strategic Partnerships Global Telecommunications Sector Jan 2000 – Dec 2004**	**Network Analysis of Strategic Partnerships Global Telecommunications Sector Jan 2005 – Dec 2009**
No log entries	1,550	580
No nodes	912	432
Mean degree centrality	1.6	1.3
Mean eigenvector centrality	0.001	0.002
Mean betweenness centrality	154	9.7
Max degree centrality	Motorola (25), Ericsson (19), AT&T (19), NTT (18), Nokia (15)	Nokia (12), Vodafone (11), Hutchison (8), Buongiorno SpA (5), China Unicom (5)
Max eigenvector centrality	Motorola (0.049), Ericsson (0.046), China Mobile (0.039), Nokia (0.037), China Unicom (0.026)	Hutchison (0.081), Vodafone (0.081), Nokia (0.080), Orange (0.034), Deutsche Telekom (0.031)
Max betweenness centrality	China Mobile (12,544), Ericsson (10,829), Motorola (8,900), AT&T (7,844), Alcatel (4,999)	Nokia (897), Hutchison (842), Vodafone (627), Google (368), Buongiorno SpA (244).

Source: Based on Thompson Reuters, SDC Platinum Database, Accessed Dec 2013

Overall, these metric and visual representations confirm the active role of mobile communications operators in the latter part of the 2000s, when the system specifications for IMT Advanced were approved in ITU-R and when mobile operators started conducting validation tests for the new core network and integrated mobile services of different generations attached to it. This change in the relationship between system developers and system operators in mobile communications represents a departure from the previous case studies. Rather than relying on technology exclusivity as a mechanism for securing rights of use in a given frequency band, the manufacturing industry opted for technology inclusivity of the main competing technologies and for reconfiguring the system to benefit both developers and operators. This flexibility, however, required a larger frequency pool, which the 800 MHz band offered due to its valuable propagation characteristics, which reduced investment in physical infrastructure, and, most importantly, due to its adjacency to an existing frequency pool for IMT systems, already established at the global level. The next section discusses how the organisation of the mobile communications industry in informal industry associations such as the WWRF, the NGMN Alliance and MIB increased communication between developers and manufacturers and informed preferences for more flexible operational rules in the 800 MHz band.

5.3.2 The Nature of Property Arrangements in the 800 MHz Frequency Pool

The informal negotiations that took place between mobile communications developers and mobile communications operators are central to the definition of more flexible operational rules for the 800 MHz band. It is important to note that, compared with the broadcasting industry, which did not specify reallocation to the 800 MHz band based on need for specific (added value) communication services, the mobile communications industry, represented by MIB at the WRC-07, made a specific link between the flexible evolution of these systems and their technology co-existence, as well as their integration with wireless local area networks, in order to justify need for the reallocation of the 800 MHz band to communication services.

Table 5.6 provides a summary of the configuration of rights at operational and collective choice level, which formed the bundle of property arrangements in the 800 MHz band. *Table 5.6* reveals that, at the operational level, the right to enter the radio resource is maintained on service excludability but, this time, at the global level. The conflict between the primary allocation of the band to the broadcasting services on the one hand and the mobile communications services on the other hand reveals the importance of maintaining some aspects of excludability – in this case service exclusivity – when managing common pool resources. As long as mobile communications are allocated on a primary basis to the band – i.e. excludability based on de facto service exclusivity, rights of use inside the band are more flexibly defined than in the previous cases discussed in this thesis. Thus, rather than relying on principles of technology exclusivity to define the rate of use in a given frequency band, mobile operators are given the flexibility to choose among a range of radio access technologies, as long as one of those technologies belongs to the IMT family of services.

Table 5.6 The Configuration of Property Arrangements in the 800 MHz Global Frequency Pool for the Deployment of IMT Systems

Property Right		**Property Arrangements in the 800 MHz Band based on IMT**
Operational Rights	*Access*	The right to enter the resource is given by membership in a geographic area (CEPT) and in a communications service club (EBU, IMT).
		The right of primary access can be de facto service exclusivity, because it grants the communications service the highest protection from non-interference by other secondary, tertiary users.
	Use	Broadcasting operators maintained rights of use of the 800 MHz frequency at RRC-06. Technology excludability was based on DVB-T for digital television broadcasting.
		After the reallocation at WRC-07, mobile operators gained rights to use the 800 MHz band, with greater technology flexibility, as part of a wider frequency pool for IMT mobile communications systems.
Collective Choice Rights	*Management*	Equal participation of both mobile operators and system developers in system design based on technology inclusion, rather than technology exclusion. Technology flexibility is ensured as long as one of the systems is from the IMT family of mobile communications.
		Information exchange as commitment to flexible operational rules is ensured from research and design phase in WWRF. WWRF founding members represented in MIB at WRC-07.
		Mutual monitoring is achieved, informally, between operators (NGMN Alliance) and developers (LTE/SAE Alliance) based on system validation tests, in order to achieve compliance with operational rules based on flexible access.
	Exclusion	The de facto right to exclude is granted, first, solely to broadcasting services (RRC-06).
		Afterwards, the de facto right to exclude is grated, on a co-primary basis, to mobile and broadcasting services (WRC-07), overturning single service primacy to broadcasting at RRC-06. In CEPT, led to a release of whole 800 MHz band in favour of mobile communications services based on IMT.

So, what changed to allow this flexibility of use? The answer rests with the organisation of the mobile communications industry, particularly with the establishment of three mechanisms to ensure commitments to the operational rules described above. First, both operators and developers participated in the design of the new system for IMT-Advanced, which communicated the technology preferences of both parties. Technology flexibility, which was desired by mobile communications operators, was negotiated in exchange for service exclusivity at the global level, which was desired by mobile communications developers, as well as operators, in order to secure investments in research and development and in network deployment. Second, information exchanges on technology preferences and complementary technology capabilities occurred from the early stage of research and development, in informal organisations such as the WWRF, rather than at the stage of decision-making in formal standardisation associations such as ETSI or 3GPP. Third, mutual monitoring was achieved, informally, between an operators' alliance (NGMN Alliance) and developers' alliance (LTE/SAE Alliance) in order to establish system requirements and conduct system validation tests prior to the formal adoption of operational rules based on flexible use and de facto service exclusive access for mobile communications at national and regional level.

5.4 Conclusions

This case has traced the process of redefining operational rules in the 800 MHz band in the late 2000s, during the process of digitisation of broadcasting services. The case makes three interesting findings about the organisation of authority in transnational resources as well as about group attributes most likely to produce transnational common goods.

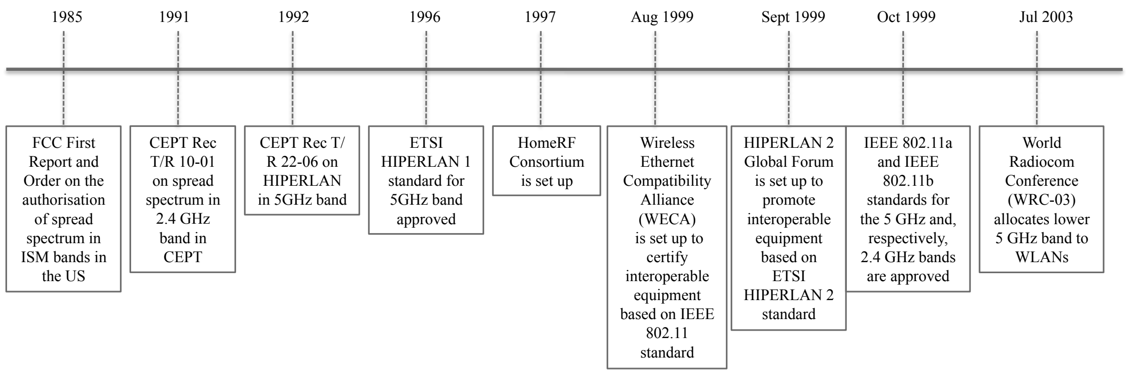
The first interesting finding is that, in the presence of a public actor with established policy venues and no technology preference for the allocation of the 800 MHz band, private actors still choose private venues to negotiate and define system specifications for new operational rules in the 800 MHz band. This is surprising because the Commission of the European Union has been depicted as a corporate actor with an established network of interests (Schneider et al 1994). Findings from the previous case, coupled with findings from the current case regarding the reasons why private actors do not initiate negotiations about operational rules for specific frequencies via public policy venues, would indicate that the public processes might pick technology "winners" and "losers" too early, inhibiting rather than facilitating, consensus over standards and, implicitly, over rules in the resource.

The evidence of private actor cooperation in the current case could fit this argument. To start, increased heterogeneity of interests and capabilities in the mobile communications industry did not inhibit cooperation. On the contrary, it facilitated communication in order to reach an early alignment between mobile operators and developers regarding the specifications of the system to be deployed in the 800 MHz band. This alignment was achieved by establishing equitable participation in system design and by engaging in early information exchange about technology preferences. This is the second interesting finding of the chapter, since the literature on the regulation of common resources predicts little private cooperation in conditions of increased heterogeneity (Agrawal 2003: 249). The third interesting finding is how private actors go about accommodating this heterogeneity, particularly heterogeneity of technology capabilities. Instead of relying on technology exclusion mechanisms, which might be higher if the process was taking place in public venues of decision-making, private actors cooperate on the development of a technology inclusive standard, which would give flexibility of use inside a given frequency allocation, as long as this allocation was protected by access exclusivity (i.e. primary service status at WRC). In order to ensure commitment to this flexible rate of use, industry actors engage in mutual monitoring and system compatibility testing (NGMN Alliance). This form of collective management of a common resource, based on flexible use and primary access resembles, more closely, principles of common exclusive property, rather than individual exclusive property, where the internal rate of use is not fixed to a given specification (IMT Advanced). The decision, taken by the mobile communications industry, to request a change of allocation in the 800 MHz to systems based on flexible use and primary access (IMT Advanced), reflects how property arrangements agreed privately, at transnational level, can co-exist with property arrangement originating from other levels of decision making, i.e. state or regional (RRC).

Chapter 6. Regulating the 2.4 GHz and 5 GHz Bands: From Devising Operational Rules to Devising Collective Choice Rules in Global Pools

This chapter follows the process of defining property arrangements in the 2.4 GHz band and 5 GHz band for use, on an unlicensed basis, by wireless local area networks (WLANs). The case analyses how different configurations of economic interests and technology capabilities among private actors had an impact on the creation of different property arrangements for the 2.4 GHz band and the 5 GHz band although, in principle, the two bands operate under similar rules based on unlicensed access and emission conditioned use. The case bears several similarities with the previous case studies discussed in this thesis and, as a result, provides useful cross-case comparisons. *Figure 6.1* offers the timeline of main events during the definition of operational rules for the 2.4 GHz band and the 5 GHz band. These events span over two decades of negotiations among industry actors in the information technology and mobile communications industry and, based on the origin of industry actors in these two sectors, link the regulation of the two bands in the United States[161] and the CEPT[162].

Figure 6.1 Timeline of Main Events in the Regulation of the 2.4 GHz Band and the 5 GHz Band



The case starts by analysing the distribution of economic interests and technology capabilities among industry actors in the information technology sector, following the opening of the 2.4 GHz band for unlicensed use by communication equipment based on spread spectrum technology in the United States (*Section 6.2*). In contrast with the established competence of the public actor in the United States, the authority of the Commission of the European Union was limited at the time, similar to the first case

[161] Situated in Region 2 of the radio spectrum.
[162] Situated in Region 1 of the radio spectrum.

study presented in this thesis. However, in contrast with all previous cases, this chapter reveals a situation of asymmetric economic interests in extracting economic value from different frequency bands, rather than solely from the 2.4 GHz band, combined with a relatively equal distribution of technology capabilities among a small number of industry actors. The case reveals that this initial distribution of interests and capabilities in the information technology industry[163] led to limited cooperation by private actors, regardless of the presence (US) or absence (CEPT) of a public actor. Specifically, out of the four cases put forward in this thesis, the initial distribution of heterogeneous economic interests and homogenous technology capabilities appears to be the least likely to result in private cooperation with the aim to provide wireless communications even if, as in the case of the 2.4 GHz band, the public actor had already defined open rules of access and emissions conditioned rules of use, establishing what can be referred to as a public common.

However, the second part of the case (*Section 6.3*) reveals how the intervention of the mobile telecommunications industry, interested in delivering data services similar to the information technology industry, changed this initial distribution among private actors by diversifying the technology capabilities available in order to deploy wireless local area networks (WLANs). The case shows that the intervention of the telecommunications industry in the technology development process increased the diversity of economic interests and technology capabilities among industry actors involved in the negotiation of technology specifications to be deployed in the 5 GHz band. This new situation of diversified interests and diversified capabilities raised the question whether the wireless technologies developed by the computing industry and the mobile technologies developed by the telecommunications industry should compete or co-exist.

Similar to the previous case study, the chapter shows that industry actors with established technology capabilities in the computing and telecommunications industry were able to change allocations in the 5 GHz band, based on flexible rules of use and

[163] The chapter shows that, in the case of the 2.4 GHz band, we are looking at the same industry actors in the information technology sector in the United States and in Europe. As it will be explained, this is because the information technology market was not as developed in Europe as in the United States in the early 1990s, and information technology companies originated in the United States were already present in the European market.

exclusive rules of access at the international level (WRC-03). This situation changed the regulation of frequencies for WLANs from a public common in the 2.4 GHz band (conditioned common use and open access) to a private common in the 5 GHz band (conditioned common use and primary access). Similar to the previous case study, the chapter reveals that this was achieved by increasing information exchanges between industry actors (IEEE 802.11 and ETSI BRAN), by establishing a private certification mechanism with responsibility to monitor and approve interoperability of equipment (Wi-Fi Alliance) and by integrating, rather than excluding, mobile telecommunications and wireless communications systems (3GPP and Wi-Fi).

6.1 The Formation of Actor Strategies in the Wider Governance of Electronic Communications

This section traces the origin and distribution of private actor strategies during the opening of the 2.4GHz frequency band to equipment using spread spectrum technologies. It is revealed that the organisation of the 2.4 GHz band as a public common, characterised by conditioned yet unlicensed use, originates in the mid 1980s in the United States. This section starts by contextualising the origin of this regulatory regime and argues that it was informed by two interdependent factors. On the one hand, the liberalisation of telematics and telecommunications markets during the Tokyo (1973-1979) and Uruguay (1986-1994) Rounds of GATT negotiations. On the other hand, the increased global competitiveness of the information technology industry originating from the United States and the global competitiveness of the mobile communications industry originating from Europe. However, the increased competitiveness of these electronic communications sectors led to different approaches to liberalisation in the United States and in Europe. Whereas the Federal Communications Commission (FCC) in the United States adopted a deregulation agenda for some parts of the radio spectrum and the electronic communications market, the European Commission in the EC/CEPT had limited competences in this field and, as a result, put forward an agenda for re-regulation that packaged liberalisation with the convergence of infrastructures and services in the electronic communications sector. Thus, whereas the FCC followed the deregulatory agenda and allowed spread spectrum technologies to populate bands already open for industrial, scientific and medical (ISM) use – such as the 2.4 GHz band – CEPT administrations focused on the harmonisation of frequency bands for the exclusive deployment of pan-European communications networks such as GSM. These approaches reflect the positions of the established industry in electronic communications at the time, which was structured in a small number of manufacturers with relatively equal technology capabilities, but with diverging economic interests for different parts of the radio resource. This distribution of equal technology capabilities and diversified economic interests in the radio resource prevented coordination for the development and use of spread spectrum technologies in the ISM bands in the 1990s and led to the fragmentation, rather than the convergence, of the electronic communications industry. Consequently, positions of rivalry and excludability in the wider radio spectrum were reinforced, rather than challenged, on both sides of the Atlantic.

6.1.1 The Structure of the System of Governance in Electronic Communications

Wireless local area networks (WLANs)[164] developed in an institutional setting characterised by minimal coordination between industries in the electronic communications sector as well as by minimal coordination in system standardisation and radio spectrum policy harmonisation across borders. However, similar to Case Study I (900 MHz band) and Case Study II (1.9-2.1 GHz band), the late 1980s and early 1990s saw a gradual international commitment to the liberalisation of the electronic communications equipment and services market via the General Agreement on Tariffs and Trade (GATT 1986-1994).

However, as detailed in Case Study I (*Chapter 3*), the process of liberalisation and deregulation uncovered different levels of competition in the electronic communications industry, particularly between the United States and the European Union. Specifically, the telecommunications industry was growing at a faster rate across the European Union, due to projects such as GSM, whereas the information technology industry was growing at a faster rate in the United States. *Table 6.1* compares the intensity in research and development of these two industries across a number of selected states in Europe and the United States. The figures confirm that the computing industry was

[164] Industry reports show that the first product to be certified as an early version of a WLAN corresponds to a device produced by Telesystem in 1988, whose dimensions were larger than a shoebox (Negus and Petrick 2009: 39, Marcus 2009: 31).

investing considerably more in research and development in the United States, whereas the telecommunications industry was more active in France, Germany and Sweden and, overall, across the EU-9 (*Table 6.1*).

Table 6.1 R&D Intensity by Industry, Business Enterprise R&D as % of Value Added

	United States		**France**		**Germany**		**Sweden**		**United Kingdom**		**EU-9**	
	1990	**1996**	**1990**	**1996**	**1990**	**1995**	**1990**	**1995**	**1990**	**1997**	**1990**	**1995**
Computers, Office Machinery	46.7	43.1	10.0	9.7	14.5	27.0	39.0	51.9	19.1	4.8	16.0	14.9
Communications Equipment & Semiconductors	17.4	21.3	32.3	32.1	16.6	11.4	68.5	59.4	16.1	13.7	19.3	18.3

Source: OECD (1999)

The figures in *Table 6.1* reveal the basic difference in the configuration of interests in the electronic communications industry in Europe on the one hand and in the United States on the other hand. Moreover, as it will be shown in the next section, they also reveal how public actors situated in the United States and across the CEPT positioned themselves in relation with two major opportunities in the electronic communications sector. On the one hand, the growth of the computing industry following the introduction of personal computing (PC), the Internet and wired local area networks (wired-LANs) in the early 1980s (Lemstra and Hayes 2008: 4). On the other hand, the growth of mobile cellular communications following the introduction of second generation digital mobile telecommunications networks (GSM, PCS) in the late 1980s. Whereas across the CEPT, the vision for deregulation was associated with a re-regulation process for the creation of pan-European networks (revisit *Chapter 4*), in the United States, the FCC interpreted deregulation as a process of eliminating anachronistic regulation and allowing technology to compete in the market.

6.1.2 The Initial Position of the Public Actor

In the early 1990s, public administrations across the EC and the CEPT were concerned with the adoption of a new model of managed competition that would balance the interests of monopoly operators in fixed line telecommunications with the interests of equipment manufacturers in the computing industry and the wireless communications industry (Hancher and Larouche 2011, Lando 1994). This tension manifested in two policy directions for the electronic communications sector in the European Community (EC). On the one hand, deregulation and the gradual opening up of infrastructures and services focused away from voice telephony over fixed line infrastructures, dominated by natural monopolies, and onto new segments of the electronic communications market, particularly mobile telephony and personal computing. On the other hand, re-regulation of the electronic communications sector focused on the introduction of converged services on integrated infrastructures such as ISDN or B-ISDN[165]. Although the European Commission had limited competences in electronic communications in the early 1990s[166], it positioned itself as a public actor by associating the wider agenda for sector liberalisation with the growth of the mobile communications and personal computing markets in Europe:

> "[…] personal communications services are likely to be based initially on combinations of existing systems such as GSM, DCS-1800 and DECT, together with intelligent network functions in the fixed network providing for mobility via the fixed network, […]. This trend will be further reinforced by the move towards portability. After desktop work stations and PCs have shown strong growth rates, demand shifted to laptops, notebooks, and pen-books and now towards full-scale Personal Intelligent Communicators (PICs) or Personal Digital Assistants (PDAs)" (EC 1994: 15).

Thus, within the EC, the process of deregulation of electronic communications markets was associated with a project of re-regulation of converged infrastructures and services in order to maintain the "strong position" obtained by the European industry in the mobile communications sector[167] (EC 1994: 14). By the mid 1990s, the policy direction for growth in electronic communications in the EC followed principles of managed competition based on the integration of pan-European infrastructures for the delivery of converged voice and data services that would maintain temporary positions of

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[165] Revisit *Chapter 4.1* for a discussion on the tensions between deregulation as part of the wider liberalisation process and reregulation as part of the single market project in the European Community.

[166] Revisit *Section 3.1.2* and *Section 4.1.2* of this thesis.

[167] The European Commission Green Paper on a Common Approach in the Field of Mobile and Personal Communication in the European Union (EC 1994) noted that "European industry has obtained a strong position in both network and terminal equipment markets in this area, and GSM is having a major impact on ensuring the world position of the global European telecommunications industry, with a resulting positive effect on its growth, competitiveness and employment" (EC 1994: 14). This approach confirms the policy direction for growth in electronic communications at the time, focusing on market integration and economies of scale within the EC/CEPT as well as on exports and competitive positioning abroad.

monopoly in fixed line telecommunications while opening up newer segments such as mobile and personal communications (Hancher and Larouche 2011: 746). Radio spectrum policy, which remained in the competence of member states, focused on the harmonisation of frequency bands in the CEPT with the end goal to replicate the creation of economies of scale in wireless equipment such as GSM.

By contrast, in the United States, the process of deregulation of the electronic communications sector took a relatively different path to economic growth, aimed at improving competition within industry as a means for technology innovation. As M. Marcus (2009), former Assistant Chief for Technology for the Federal Communications Commission (FCC) recalls, this approach to deregulation, with political foundations in the Carter and Reagan administrations, is considered to have levelled the playing field for developers of communications technology without burdening the market with "prescriptive spectrum regulation"[168] (Marcus 2009: 30).

This policy approach contributed to the adoption of the *Report and Order in the Matter of Authorisation of Spread Spectrum and other Wideband Emissions not Presently Provided for in the FCC Rules and Regulation* (1985). The FCC First Report and Order (1985) is widely considered "the formal starting gun for the WLAN industry" (Negus and Petrick 2009: 38). In short, the FCC First Report and Order (1985) authorised unlicensed access to low power and limited range devices using spread spectrum technology in the industrial, scientific and medical (ISM) frequency bands at 900MHz, 2.4 GHz and 5.8GHz in the United States, which were already operating a public

[168] M. Marcus (2009) noted that, at the time, some senior officials in the FCC were particularly motivated to "remove anachronistic barriers to technology and having faith in marketplace forces to use the newly available technology for its highest and best use. They were also "fail/safe" decision that obligated no one to use a specific technology and displaced no existing users" (Marcus 2009: 20). As discussed in *Chapter 4* of this thesis, the FCC applied this approach in mobile cellular communications in the early 1990s, when it adopted more than one standard for second generation mobile communications systems. This reveals the difference in regulatory approach at the time, as well as the different considerations that linked radio spectrum policy to market growth on both sides of the Atlantic. To showcase this difference, the European Commission (1994) noted that "There has been concern in the US that delays in introducing digital technology are allowing the GSM standard an opportunity to dominate non-European markets […] on the other hand, the FCC decision to refrain from action to promote on a single second generation system standard has led to a considerable increase in the rate of experimentation and this may lead to rapid roll-out of innovative new mobile services in the US" (EC 1994: 142).

commons regime based on unlicensed but conditioned access (i.e. interference conditioned access) for ISM applications:

> "Spread spectrum systems are also being authorised under Part 15 for general usage in the 902-928MHz, 2,400-2,483.5MHz and 5,725-5,850MHz ISM bands. […] These systems may operate within these bands within a maximum output power of 1 watt. […] Spread spectrum systems are allowed to operate within the ISM bands only on a non-interference basis to other operations that have been authorised the use of these bands under other Parts of the Rules. They must not cause any harmful interference to these operations and must accept any interference which these systems may cause to their own operations" (FCC 1985: para 24).

The scope of this authorisation requires further analysis in order to understand the response of industry actors to the decision of the FCC (1985). Two policy choices are important in this analysis: a) the choice of technology (i.e. spread spectrum) and b) the choice of radio resource (i.e. the ISM frequency bands). Their contextualisation provides evidence for the slow response of the industry to develop the WLAN market throughout the 1990s in the US as well as across the CEPT.

The choice of spread spectrum systems[169] was one of the technology options considered by the FCC in the 1980s in order to change the use of prescriptive regulation of spectrum "written to reflect the technologies available at the time and reasonably anticipated in the future" (Marcus 2009: 20). In his position as Associate Chief for Technology in the FCC, and with previous experience in the defence sector, M. Marcus proposed a "spread spectrum deregulation project" that would adapt this technology from military to civilian uses[170] (2009: 20). However, Marcus clarifies that the choice of technology was not made in relation to a product or service range but to "promising technologies blocked by anachronistic regulations"[171]:

[169] Several types of spread spectrum technologies were defined: direct sequence systems, frequency hopping systems, time hopping systems, pulsed FM systems and hybrid spread spectrum systems (Appendix B, Report and Order, FCC 1985). Thus, the prescriptive regulation did not refer to a particular standardised technology but, in fact, to a broad family of methods for applying spread spectrum.

[170] Spread spectrum technology was extensively used in the military due to its resistance to jamming and intercepts.

[171] At the time, M. Marcus had identified three such promising technologies: spread spectrum, adaptive antennas and millimeter wave bands (>30GHz) (Marcus 2008). In his account of the First Report and Order (FCC 1985), M. Marcus noted that "the FCC staff did not anticipate at the time that spread spectrum would be a possible technology for general land mobile applications, e.g. CDMA cellular, but rather that it could be valuable in at least niche applications" (Marcus 2009: 21-22).

> "The spread spectrum goal at the time was not to introduce a specific class of products, such as wireless local area networks [WLANs], or even a specific band, but rather to create relatively clear opportunities for this technology to reach market in order to encourage investment in R&D" (Marcus 2009: 20).

With spread spectrum as one of the technologies to be allowed in the radio resource, the question moved onto the frequency range to be considered for access and use. The choice of frequency range – i.e. 900MHz, 2.4 GHz and 5.8GHz (ISM bands) – showcases the importance of private actors in the population and regulation of radio waves. Three industry sectors in electronic communications opposed access of spread spectrum equipment on their allocated frequency bands or in the vicinity of their allocated frequency range: a) the military sector, b) the broadcasting sector and c) the mobile cellular communications sector. For the military sector, allowing spread spectrum equipment on the radio resource would encourage the development of civil applications with capacity to breach national security or to resist smart jamming based on the spread spectrum equipment of the time (Marcus 2009: 24). For the broadcasting sector – operators and manufacturers alike – allowing spread spectrum equipment on their licensed allocations would "seriously degrade" the quality of their television services by interfering with the picture quality (FCC 1985: para 6). Lastly, for the mobile cellular communications industry, allowing commercial spread spectrum equipment in licensed bands for mobile communications services would not only interfere with these services but, most importantly, would have the potential to compete with existing cellular systems using FDMA or TDMA access methods[172] (FCC 1985: para 8, Marcus 2009: 25).

The strong opposition of the broadcasting and mobile cellular industry to overlay spread spectrum systems on their licensed bands limited the choice of frequency ranges available for this technology. This focused the attention on the industrial, scientific and medical (ISM) frequency bands at 900MHz, 2.4 GHz and 5.8GHz for two reasons. First, the ISM radio spectrum was already populated by a variety of low power and

[172] As discussed in *Chapter 3*, *Section 3.2*, FDMA, TDMA and CDMA are different channel access protocols used in terrestrial and satellite mobile communications. FDMA is a technology that divides the bandwidth into frequencies and assigns them for a communication. TDMA is a technology that assigns calls to different time divisions on the radio band. CDMA – which is used in third generation mobile communication as discussed in *Chapter 4* – uses a spread spectrum technique that allocates a unique code to elements of a conversation and spreads it in different frequencies. In the early 1990s, the two established techniques in mobile communications were FDMA and TDMA.

limited range devices, including microwaves, microphones, remote controlled devices and cordless phones. Second, the ISM radio spectrum was already regulated to allow access to applications on an unlicensed and power conditioned basis that, similar to the regulation for spread spectrum equipment, is required to cause no harmful interference to other applications in the band and to accept their potential interference (FCC 1985: para 24). In this case, spread spectrum devices were permitted access to frequency bands already regulated as public commons – i.e. with no allocation for individual exclusive use but with conditioned access.

The choice of ISM radio frequency bands for spread spectrum technologies reveals important considerations about the role of the public actor in determining operational rules of access and use in the radio resource. Far from creating open access regimes in the ISM radio frequency pool, the measures adopted in the First Report and Order (FCC 1985) reveal some of the technology constraints imposed by industrial appropriators of the wider radio resource. The explanation comes from the regulators themselves. As one of the key contributors to the FCC Report and Order (1985), M. Marcus (2009) noted that the choice of maximum output power for spread spectrum devices at 1W (watt) was also informed by considerations that higher output powers "would be a threat to the land mobile establishment" by competing directly with cellular technologies of the day – i.e. FMDA and TDMA (Marcus 2009: 29). Similarly, the allocation of spread spectrum equipment in the ISM frequency bands reveals the more favourable position of the established industry – mobile cellular and broadcasting – for this assignment, given that devices in the ISM band were less likely to contest their co-existence with spread spectrum devices or, as Marcus put it, given that "microwave ovens do not protest" (Marcus qtd in Lemstra et al 2011: 47). Thus, allowing spread spectrum equipment to gain access to the ISM bands did not disrupt any configurations of rivalry and excludability in the ISM band itself as well as in other frequency bands where the broadcasting and mobile communications industry was benefiting from exclusive access and use.

Overall, the choice of regulatory framework adopted by the FCC in the early 1990s focused on deregulating both the radio resource and the electronic communications market in order to provide the possibility for certain technologies – such as spread spectrum – to develop, while protecting the commercial interests of the established communications industry[173]. By contrast, the choice of regulatory framework taking shape in the EC and, more widely, in the CEPT in the early 1990s focused on integrating infrastructures and converging services in order to replicate the creation of economies of scale similar to the deployment of GSM networks in mobile communications. However, most importantly, differences in the presence and regulatory preference of the public actor in the US and in the EC/CEPT did not disrupt configurations of rivalry and excludability in the radio resource for the established industry. On the contrary, similar to the previous case studies, the technology preferences of the established industry conditioned the configuration of rules of access (i.e. choice of frequency band) and rules of use (i.e. choice of equipment power limits) for spread spectrum technologies in the ISM bands so that the measure had minimum redistributive effects for established interests in the radio resource. The next section provides further evidence which explains the distribution of interests and capabilities among the established industry, showing that, at the time, the computing and mobile communications industry was consolidated in a small number of players with relatively similar technology capabilities but with diversified economic interests in their respective markets. This configuration of interests and capabilities contributed to the initial fragmentation of the wireless communications market, leading to reduced coordination in the development and standardisation of spread spectrum technologies and, subsequently, to reduced levels of use of the radio resource for low power and low range wireless services.

6.1.3 The Initial Distribution of Private Interests and Private Resources

The representation of private actors in the distribution of access and use of the radio spectrum in the decade from the mid 1980s to the mid 1990s indicates their diversified interests in the growth of two distinct market segments – information technology and mobile cellular communications – in the United States and in CEPT Member States. The initial heterogeneity of private interests in the electronic communications market translated into limited investment in the development of low power and low range

[173] In fact, M. Marcus proposes that his attempts to promote similar technology and regulatory approaches in the FCC in the aftermaths of the First Report and Order (1985) led to the reorganization of his department, followed by his “internal exile” in the Enforcement Bureau of the FCC (Marcus 2009: 30).

devices using the ISM bands. This situation is confirmed by industry representatives who indicate that the wireless communications market did not experience the immediate growth that the cellular communications market did[174]. In fact, Negus and Petrick (2009) show that almost a decade after the adoption of the First Report and Order (FCC 1985), there were approximately one hundred devices per year certified for the ISM frequency bands:

> "The reaction to the FCC's monumental allowance of unlicensed spread spectrum systems in 1985 was not an immediate flood of equipment authorisation applications. By today's standards, it was not even a trickle" (Negus and Petrick 2009: 39).

The remainder of this section explores the distribution of capabilities in the information technology and the mobile cellular communications markets in order to explain the limited interest of the established industry in populating the ISM bands with spread spectrum equipment in the early 1990s. In the late 1980s, the information technology industry in the United States was involved in the development of wired local area networks (wired LANs) that would facilitate access to newly commercialised Internet services. After the introduction of proprietary equipment, the main manufacturers in computing were concerned with the adoption of a wired LAN standard in order to develop the market (Lemstra and Hayes 2011: 35). Negotiations over the standardisation of wired LANs took place in the Institute of Electrical and Electronic Engineers (IEEE) – the most established association for electronic communications in the United States. Following a series of negotiations in the mid 1980s, the main industry actors could not agree on a single set of technical specifications, which led to the adoption of three standards for wired LANs by the IEEE: a) Ethernet (or IEEE 802.3 promoted by XEROX, Intel and 3Com); b) Token Bus (or IEEE 802.4 promoted by General Motors) and c) Token Ring (or IEEE 802.5 promoted by IBM)[175].

In parallel, the wireless industry was looking at three different technologies that would replicate principles of local networking using electromagnetic technology[176]: a)

[174] However, from the mid 2000, wireless and mobile cellular communications had a relatively similar growth trajectory, becoming the two largest market segments in the world in electronic communications using the radio resource (Marcus and Neu 2013, Negus and Petrick 2009).
[175] Soon after, however, Ethernet established itself as the dominant standard (Valovic 1990).
[176] The development of wireless LANs (WLANs) came from a requirement to enhance mobility in offices, campuses and warehouses, where wired networking was not

microwave technology; b) radio technology (where the mid range ISM bands would fit) and c) infrared technology (Computing 1993). Similar to the consolidation of the industry for wired LANs, these technologies were supported by established private actors in the United States. Motorola was backing microwave technology and was interested in deploying wireless LANs in the 18GHz frequency band – rather than in the lower ISM bands – in order to establish a form of exclusivity in this unlicensed band through an early market entry. The National Cash Register (NCR), acquired by AT&T in 1991, was backing radio technology and was interested in deploying wireless LANs in the 900MHz frequency band opened for spread spectrum equipment in the United States. In fact, by the mid 1990s, NCR was one of the four established industry actors – NCR, Proxim, Symbol and Aironet – developing spread spectrum wireless LANs for ISM frequency bands, particularly for the 900MHz band, in the United States (Negus and Petrick 2009: 37).

However, the wired LAN and wireless LAN markets grew at different speeds in the early 1990s. Whereas the wired LAN market was growing at a considerable rate following the rising adoption of the Ethernet standard, the wireless LAN market was still fragmented, experimenting with three technologies – microwave, radio and infrared – in different frequency bands. In fact, in the early 1990s, NCR attempted to standardise wireless LAN as a variant to one of the wired LAN standards adopted in the IEEE. Representing NCR, and later becoming the central figure in the standardisation of wireless LANs, V. Hayes (2011) recalls that the IEEE 802.3 Ethernet standards group voted against the development of a wireless extension to the standard and in favour of establishing a new standardisation group (Lemstra et al 2011: 63). This position reveals the heterogeneity of interests in the wired and wireless LAN market as well as the different stages in the development of these markets:

> "The development team [at NCR] recognised that having an already established group within IEEE 802 to sponsor a new physical layer was a much faster process than trying to start a new standard from scratch" (Lemstra and Hayes 2008: 9)

In short, the diversity of economic interests in the three technologies for wireless LAN – i.e. microwave, spread spectrum and infrared – had limited the scope for standardisation of these products, leading to dispersed investment in different

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feasible. Thus, similar to cellular technology, wireless LAN technology targeted businesses rather than individual consumers first.

equipment for different frequency bands. This situation explains why, by the mid 1990s, "WLANs found almost no success in selling to enterprises or campus environments as wired LAN replacements or enablers of mobility" (Negus and Petrick 2009: 36). First, wireless LANs had less speed than wired LANs, achieving 2Mbs compared with over 15Mbs in data transfer rates. This limitation derived from the nature of commercial microwave or spread spectrum technology itself, which had either power constraints and bandwidth constraints in the lower ISM bands or manufacturing cost constraints in higher microwave bands (LAN Times 1994). Second, wireless LANs equipment was priced at around $1,500 in the early 1990s, considerably more expensive than a $500 Ethernet card (Negus and Petrick 2009: 36, Lemstra et al 2011: 113). Third, wireless LANs used proprietary and non-interoperable technologies, which maintained high manufacturing costs, high fragmentation of the market and low occupancy of the frequency bands opened, among other applications, for new wireless technologies. Thus, by the mid 1990s, wireless LANs using either spread spectrum, microwave or infrared technology were estimated at no more than 1% of the total LAN market (Valovic 1990).

The heterogeneity of interest exhibited by the information technology industry in the United States in the 1990s was matched by a similarly diverse and concentrated mobile cellular communications industry in the EC/CEPT[177]. On the one hand, the mobile cellular communications industry in Europe was focused on improving their return on investment in GSM networks with a growing customer base (revisit *Chapter 4.1*). Additionally, the 900MHz band designated for ISM services in the United States was designated for GSM services in the CEPT, which limited international frequency harmonisation and, subsequently, the market potential of wireless LAN equipment manufactured for this band, such as the WaveLAN card produced by NCR. On the other hand, the mobile cellular communications industry in Europe had already invested in a competing technology for local wireless communications, standardised as Digital Enhanced Cordless Telecommunications (DECT) in the CEPT in 1987 and, similar to

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[177] The distribution of interests and resources in the electronic communications industry in the early 1990s also reflects differences in the growth of information technology and mobile communications on both sides of the Atlantic. The major players in information technology were based in the United States and, as a result, this market grew from the United States to the rest of the world. Conversely, the major players in mobile cellular communications were based in Europe and, as a result, this market grew from the EC/CEPT to the rest of the world.

the GSM standard, passed onwards to ETSI in 1988. Supported by the five largest manufacturers of telecommunications equipment in Europe – Alcatel, Ericsson, Phillips, Nokia and Siemens – DECT terminals were envisioned to connect to a wireless port when indoors and to a radio base station when outdoors. Because DECT had a radius of 25-100m, compared with the 2-10km for GSM, it was developed to compete directly in the wireless LAN market and, as a result, received exclusive allocation in the 1,880-1,900 MHz frequency range in the CEPT in 1993. Thus, the focus of the mobile cellular communications industry in Europe was on the development of pan-European standards with potential to create economies of scale at home and be exported abroad – such as GSM or DECT – rather than on investing in new research and development for spread spectrum technology.

Overall, this initial distribution of economic interests and capabilities in information technology and mobile cellular communications in the early 1990s reveals why private actors had little incentives to coordinate their development and standardisation activity for wireless equipment using spread spectrum technologies in the ISM bands. On the one hand, both industry sectors were concentrated in a small number of private actors with relatively equal technology capabilities. On the other hand, these private actors had heterogeneous economic interests in different technologies (e.g. microwave, spread spectrum, time division[178]) to be deployed in different radio frequency ranges (e.g. 900MHz and 18GHz) with different configurations of rivalry and excludability (e.g. 900MHz in the US and in Europe). This fragmentation within the electronic communications industry and between the radio regions with two of the most developed electronic communications markets – i.e. Europe (Region 1) and Americas (Region 2) – raised the possibility to open the 2.4 GHz frequency band to spread spectrum technology in the CEPT in order to achieve international harmonisation of this frequency band for this type of technology. As it will be discussed in the next section, one of the main proponents of this measure was NCR/AT&T, who was actively involved in the standardisation of equipment for the 2.4 GHz band in the IEEE as well as in ETSI. However, as it will be revealed in the next section, operational rules of access and use of the 2.4 GHz band differed between the United States and the CEPT,

[178] As indicated above, time division refers to the TDMA technology used in GSM and DECT standards.

reflecting the interests of the established mobile cellular communications industry in Europe.

6.2 The Process of Private Rule-Making in the 2.4 GHz Band

The initial configuration of diversified economic interests combined with a relatively equal distribution of technology capabilities among a small number of industry actors, limited the private actors' capacity to negotiate collective arrangements for harmonised access and use to the 2.4 GHz on both sides of the Atlantic. Although the 2.4 GHz band was opened to spread spectrum technologies in the early 1990s in the CEPT, following proposals by NCR/AT&T to harmonise the band across the United States and across Europe, rules of access onto the band differed between the two radio regions. These differences reflected the position of the telecommunications industry in Europe and reinforced, rather than challenged, the established positions of rivalry and excludability in the radio frequencies that could facilitate WLANs. In addition, these conditions of fragmentation intensified distributional concerns over the rate of use of the radio resource for WLAN equipment, leading to conflict over the technological specifications to be standardised in order to harvest the 2.4 GHz band for local area networks. Throughout the 1990s, three main standards were competing in the market for WLANs, each with different configurations of resource access and use embedded in them: IEEE 802.11 for the 2.4 GHz band (based on Ethernet with spread spectrum radio access), ETSI HIPERLAN 1 for the 5 GHz band (based on Ethernet with GSM radio access) and IEEE Home RF for the 2.4 GHz band (based on Ethernet with shared wireless and DECT radio access). Although competition between them prevented the growth of the WLAN market throughout much of the 1990s, the activity of the information technology and telecommunications industry in the two formal associations – IEEE in the United States and ETSI in Europe – reconfigured the market into a situation of diversified interests and diversified technology capabilities. As in the previous case study (*Chapter 5*), this new configuration permitted the exchange of information about technology preferences across the two industry associations and paved the way for the creation of the Wireless Ethernet Compatibility Alliance (WECA) to further system interoperability and certification.

6.2.1 Negotiating Rules of Access

Whereas the FFC opened the ISM bands (i.e. 900MHz, 2.4 GHz and 5.8GHz) to spread spectrum equipment in 1985, the CEPT in Europe finalised its recommendations for the opening of the 2.4 GHz ISM band only in 1992, following a series of negotiations regarding the technology specifications for the wideband data transmission systems to be allowed unlicensed access in this band. However, in 1992, the CEPT adopted the *revised Recommendation T/R 10-01 for Wideband Data Transmission Systems Using Spread Spectrum Technology in the 2*.5 GHz *Band* (CEPT 1991a), which stipulated that:

> "The band 2,400-2,500MHz be used on a non-interference and non-protected basis for Wide Band Data Transmission Systems using spread-spectrum technology with a minimum aggregate bit rate of 250kbit/s. The total power in this frequency range shall not exceed -10 dBW e.i.r.p [=100mW output power][179]" (Art 1, CEPT 1991a, information in brackets added).

In addition, CEPT Recommendation T/R 10-01 (1992) adopted similar rules of access onto the 2.4 GHz band as those featured in the FCC First Report and Order (1985), stipulating that CEPT member states "shall not require an individual license for the use of Wide Band Data Transmission Systems using spread-spectrum technology terminals" (Art 3, CEPT 1991a). Although CEPT Recommendation T/R 10-01 adopted a similar approach to opening the 2.4 GHz band for unlicensed access, it differed from the FCC Report and Order (1985) in its provision of power emissions permitted onto the band. Essentially, these differences translated into distinct rules of access onto the 2.4 GHz frequency band in the United States and across the CEPT, guided by the different configuration of interests of the mobile communications market in Europe.

In 1990, the European Radicommunications Committee (ERC) of the European Conference of Postal and Telecommunications Administrations (CEPT) issued a report that discussed several technology pathways for the introduction of Radio Local Area Networks (RLANs or WLANs)[180]. These technology pathways reflected the

[179] It should be noted that -10dbW e.i.r.p (effective isotropic radiated power) is one way of measuring the power limit for electronic devices. This measure is equal to 100mW/MHz output power.

[180] The purpose of the study was based on "an increasing need for the introduction of computer terminals and peripheral equipment into the business and industrial environments. Currently, information is exchanged between such equipment by cable, resulting in a rigid hardware structure" (CEPT 1991a). In this context, WLANs were

fragmentation of the industry in electronic communications as well as the position of European industry actors in the wider sector:

> "[…] the ERC has come to the preliminary view that more than one technology and frequency band would be necessary to meet the requirements of the various applications" (CEPT 1991b).

The ERC *Report on the Harmonisation of Frequency Bands to be Designated for Radio Local Area Networks* (CEPT 1991b) suggested three technology and frequency combinations that would meet these requirements: a) spread spectrum technology (in the ISM bands with limited bandwidth); b) microwave technology (in the 18GHz band with balanced bandwidth and penetration capacity) and c) infrared technology (in the over 50GHz bands with considerable bandwidth). It is clear that these options corresponded with the three technology preferences of the information technology industry in the United States at the time. In particular, they represented the preference of Motorola for microwave technology in the higher frequency bands and the preference of NCR for spread spectrum technology in the lower ISM frequency bands. At the time, NCR had a specific interest in the promotion of spread spectrum technology in the 2.4 GHz band in Europe, as this frequency range required the least alterations to its WLAN equipment produced for the 900MHz band in the United States. This explains why, in the early 1990s, representatives of NCR were leading proposals to standardise wireless LANs in the IEEE in the United States (in Working Group IEEE 802.11) as well as in ETSI in Europe (in Technical Committee ETSI RES 10).

However, the European industry responded in a reserved manner to the proposal to open the 2.4 GHz band for spread spectrum technologies because the established telecommunications industry in the CEPT was already promoting DECT systems based on TDMA, as a direct competitor of the WaveLAN products promoted by NCR. Industry representatives confirmed this position at the time. Representing NCR, C. Links (2011) certified that "Olivetti […] had a vested interest in DECT and considered wireless LAN a potential competitor" (Links qtd in Lemstra et al 2011: 119). Similarly, representing Olivetti, A. Bud (1993) noted "There is no question that you can build radio LANs with spread spectrum and they work. It's a valid technology for doing it but, in our view, DECT is much better. DECT is a fully open, interworking network, and spread spectrum isn't" (Bud qtd in Woolnough 1993).

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viewed by the ERC "as a way of replacing cables for the connection of data networks" (CEPT 1991b).

Table 6.2 Frequency Allocations in the 2.4 GHz Band in Selected States/ Regions

2.4 GHz Allocations	Maximum Output Power	Maximum Channel Bandwidth	Standard
United States	1W (FHSS and DSSS)	1 MHz	IEEE 802.11
CEPT	10 mW	100 kHz	ETS 300 328
Japan	10 mW	20 MHz	-

Source: Based on Eroglu (1998)

This competitive stance between the two technologies – i.e. spread spectrum versus time division – was translated into the regulation of the 2.4 GHz band in the CEPT in the early 1990s. The ERC Report (CEPT 1991b) on wireless LANs made clear reference that, in Europe, "the DECT system has been developed in the 1,880-1,900MHz band offering speech and data facilities which may meet some of the RLAN requirements" (CEPT 1991b). This position reflected the trade-offs in the electronic communications sector at the time. On the one hand, rules of access onto the 2.4 GHz frequency band were to be altered in order to allow the deployment of commercial spread spectrum applications in the 2.4 GHz band and, subsequently, the international harmonisation of this band as proposed by NCR. On the other hand, rules of access onto the 2.4 GHz frequency band stipulated different output power levels – i.e. 1W in the US and 100mW in the CEPT – so that this low power and low range technology did not disrupt the position of greater power or greater range technologies (e.g. DECT) already deployed in other parts of the radio spectrum. This position was reinforced in CEPT Recommendation T/R 10-01 (CEPT 1991a), which opened the harmonised 2.4 GHz frequency band to wideband data transmission systems using spread spectrum technology but contextualised it in a manner that would reflect positions of interest in the development of WLANs in Europe. In particular, CEPT Recommendation T/R 10-01 was amended in 1992 to reflect the start of the High Performance Radio LAN (HIPERLAN) standardisation project in ETSI – a competing technology facilitating higher data rates and, subsequently, higher output powers, which would be singularly deployed in the 5 GHz frequency range:

> "However, it is recognised that the future ETSI HIPERLAN standard, requiring higher data rates, will necessitate a more predictable sharing environment. Therefore, CEPT is in the process of developing a separate Recommendation for HIPERLANs operating in the 5 GHz range and in the

> band 17.1-17.3GHz. The DECT system developed by ETSI also provides RLAN facilities" (CEPT 1991a, Introduction).

This provision showed that, when defining rules of access in the 2.4 GHz frequency pool at the regional level in Europe, the positions of rivalry of established industry actors in the wider radio spectrum were considered in order to reflect previous or future investments in technology systems such as DECT (1,880-1900MHZ band) or HIPERLAN (5 GHz and 17GHz bands). In doing so, CEPT Recommendation T/R 10-01 (1991a) reinforced, rather than challenged, the established positions of rivalry and excludability in the radio frequencies that could facilitate WLANs. In fact, the limit of 100mW output power for devices using spread spectrum technology in 2.4 GHz band doesn't only reveal a restriction on considerations of interference in order to reduce coordination problems but, possibly, a restriction on considerations of competition in order to minimise distributional issues in the wider radio resource with consequences in the wireless equipment market. In this context, the next section provides further evidence that the opening of the 2.4 GHz band in the CEPT did not lead to an immediate increase in the rate of use of this frequency band or, more specifically, to an immediate increase in the efficient use of this band. Rather, the operation of the 2.4 GHz frequency pool as a public common – i.e. with unlicensed but with power conditioned access for several applications – escalated the problem of distributing use of the resource according to the technology capabilities of established industry actors, leading to limited coordination in the standardisation and certification of WLAN equipment to be deployed in these open bands.

6.2.2 Negotiating Rules of Use

The harmonisation of rules permitting the deployment of spread spectrum devices on the 2.4 GHz band in the CEPT did not lead to an immediate increase in the use of this band by this technology. Instead, it intensified distributional concerns over the rate of use of the radio resource for WLAN equipment along the technology capabilities of the established information technology and telecommunications industry. Because these established manufacturers had diverging interests and relatively equal technology capabilities, they could not agree on a single set of specifications to encompass all their technology preferences for WLAN. This lack of coordination manifested itself in the creation of complex standards for wireless LAN products to be deployed in different bands and with different technology specifications, depending on their supporting interests. Three of these standards were the IEEE 802.11 WLAN standard for spread spectrum in the 2.4 GHz band, the ETSI HIPERLAN standard developed for the 5 GHz band and the IEEE HomeRF standard developed as a hybrid between IEEE 802.11 WLAN and DECT for the 2.4 GHz band. Similar to the first case study presented in this thesis (*Chapter 3*) the complexity of these standards resulted from the relatively equal distribution of technology capabilities among industry actors supporting them. Unlike the first case study (*Chapter 3*) – where the single GSM standard was agreed for the 900MHz frequency pool – the diversity of economic interests among these private actors, distributed across different bands, led to a lack of industry coordination in equipment standardisation and certification and, subsequently, to limited use of this technology in the 2.4 GHz and the 5 GHz band.

The IEEE 802.11 WLAN standard was developed in the Institute of Electrical and Electronics Engineers (IEEE), soon after the IEEE Ethernet Working Group (IEEE 802.3) rejected the proposal made by NCR to standardise a wireless extension to the system. Instead, NCR, represented by V. Hayes, created and chaired the IEEE 802.11 Working Group for WLANs in 1990 (Lemstra and Hayes 2008: 10). The group was tasked to start the standardisation process from scratch and to agree on a new Media Access Control (MAC) layer and a Physical (PHY) layer, rather than relying on previous work conducted by the wired LAN industry. This meant that the technology preferences of the participants had to be negotiated and realigned. From the start, the IEEE Working Group 802.11 gathered representatives of established private actors in wired and wireless LAN, including NCR and Motorola, as well as potential users of WLAN technologies such as Olivetti and Apple. However, diversified interests in the group, combined with the relatively equal distribution of capabilities among them, led to a lack of agreement on a single technical specification related to the physical (PHY) layer (Lemstra and Hayes 2008: 10). Similar to the second case study addressed in this thesis (*Chapter 4*), the formal decision-making rules established in the IEEE prevented the industry from adopting a single standard. The Chairman of the IEEE 802.11 Working Group, V. Hayes, recalls that two technologies were put to a vote for spread spectrum –frequency hopping versus direct sequence – and “neither of the two modulation techniques obtained the requisite 75 per cent level of support” (Hayes in Jakobs, Lemstra and Hayes 2011: 69). Subsequently, by the mid 1990s, the Working

Group proposed a standard with three physical layers, corresponding to the different industry actors backing then: an infrared layer supported by Motorola, a direct sequence spread spectrum supported by NCR and a frequency hopping spread spectrum support by Proxim. On the negotiations that took place in the IEEE 802.11 Working Group in the early 1990s, Negus and Petrick (2009) noted:

> "802.11 was focused primarily on developing a wireless version of the then successful 802.3 (Ethernet) wired networking standard being deployed in high volume across enterprise and campus environments. But the working group experienced internally the same frequency hopping versus direct sequence 'battle' that was happening in the marketplace for the proprietary products of the day. […] These three PHYs were not only incapable of interoperating with each other but also the direct sequence and frequency hopping PHYs, both at 2.4 GHz, caused significant mutual interference if co-located" (Negus and Petrick 2009: 41).

By contrast, the standardisation of WLANs in Europe focused on the development of specifications for the 5 GHz, rather than the 2.4 GHz band. As explained in the previous section, a year after CEPT passed Recommendation T/R 10-01 (1991) on granting access to the 2.4 GHz band to equipment using spread spectrum technologies, it revised the Recommendation to note that:

> "there is also a requirement for RLAN systems operating in a predictable sharing environment and enabling medium and high capacity data transfer rates with good frequency re-use capability which would be met in frequency bands around 5 GHz and in the band 17.1-17.3 GHz for which ETSI had decided to develop a standard for a "High Performance European Radio LAN (HIPERLAN) and for which CEPT is intending to develop a Recommendation in 1992" (CEPT T/R 10-01)

When breaking down this statement, it is revealed that the standardisation process for WLANs in Europe took a different route. Instead of developing a standard to compete with IEEE 802.11[181] for the low power and implicitly, for the limited data transfer equipment, the industry in Europe focused on the development of a new WLAN standard with considerably higher capacity for data transfers – i.e. HIPERLAN (20 Mb/s). However, because of interference restrictions in the ISM bands – such as the 2.4 GHz band – new spectrum allocations had to be made in higher bands at 5 GHz and 17 GHz bands, which would provide for less competition in the radio resource environment and, most importantly, the potential to develop a new range of wireless

[181] It can be considered surprising that this competitive route was not selected, taking into account that regional competition between standards was, and still is, commonplace in technology markets, especially in communications markets.

LANs that would directly compete with the wired LANs (Ethernet) in data transfer rates. This strategic positioning was promoted by NCR, who proposed the creation of an ad hoc working group for HIPERLAN in ETSI, via the CEPT:

> "Hayes [Vic Hayes] was invited to participate as industry representative in the CEPT project team on RLAN [Radio LAN or Wireless LAN], and in the ETSI Radio Equipment and Systems (ETSI RES) ad hoc committee on RLAN. This provided the NCR team […] with a unique position from which to leverage its activities in the IEEE and ETSI, and to align as far as (politically) possible the activities in the two standards-setting bodies" (Jakobs, Lemstra and Hayes 2011: 69).

Although the development of ETSI HIPERLAN 1 was completed in 1996, following initial cooperation with IEEE 802.11, the standard was considered too complex and too costly compared with existing technologies and, subsequently, was not adopted by the market (*Table 6.3*). Thus, although the rules of access to the radio resource were changed for HIPERLANs to ensure their de facto exclusivity in the 5 GHz and 17 GHz band, the complexity of the standard prevented it from being deployed in the market for WLANs. The fragmentation of the wireless LAN market, with interests for different bands and different technologies, restricted the response of the market to HIPERLAN. Similar to the situation in IEEE 802.11, the diversity of interests in ETSI HIPERLAN contributed to the complexity of the standard. Participants in ETSI RES 10 – the group that standardised HIPERLAN 1 from 1992 to 1996 – represented both the established information technology industry (NCR, Motorola, Apple and Olivetti) as well as some of the established industry players in telecommunications in Europe (BT, Deutsche Bundespost), leading to the creation of a standard that based its architecture on the Ethernet standard – similar to IEEE 802.11, but borrowed the modulation technology for radio transmission from GSM (Mallick 2003: 61).

Table 6.3 Main WLAN Standards of First Generation

Standard	Modulation	Data Rate	Main Industry Developers
IEEE 802.11	Infrared	1-2 Mb/s	Motorola
	FHSS Frequency Hopping Spread Spectrum	1-2 Mb/s	Proxim
	DSSS Direct Sequence Spread Spectrum	1-2 Mb/s	NCR
HIPERLAN 1	CSMA/CA	24 Mb/s	NCR, Apple, Plessey

Source: Lemstra et al (2009), Pareek (2006)

A third standard for WLANs received the support of established players in the information technology and telecommunications market in the 1990s. Entitled HomeRF, the standard was promoted, in the mid 1990s, by a consortium of established information technology developers (Proxim, Intel, IBM and Microsoft) and established telecommunications developers (Siemens, Motorola, Philips). HomeRF was designed to integrate elements of the IEEE 802.11 technology (frequency hopping) with elements of the DECT technology (TDMA) used in telecommunications. As Jakobs et al (2011) noted, the standard was proposed because the industry felt that the IEEE 802.11 standard did not integrate telephony services in its specifications (Jakobs, Lemstra and Hayes 2011: 70). Although WLAN equipment based on the HomeRF standard was produced in the late 1990s, its specifications came in direct competition with the IEEE 802.11 standard (direct sequence versus frequency hopping) as well as with the HIPERLAN standard (2.4 GHz versus 5 GHz).

Overall, the configuration of the industry around the three standards described above – IEEE 802.11, ETSI HIPERLAN 1 and HomeRF – reveal three important considerations about the relationship between preferences for technology specifications and the configuration of operational rules in the radio resource. On the one hand, the diversification of economic interests in harvesting different frequency bands for the development of different technologies led to the fragmentation of the radio resource and, subsequently, to difficulties in building economies of scale that could drive down prices for WLANs. On the other hand, the entry of telecommunications developers in the standardisation process for WLANs shifted the distribution of technology capabilities in the industry from a relatively equal distribution among a small number of developers in information technology to more diversified capabilities entering the standardisation process. The next sections explore the extent to which this new configuration of diversified interests and diversified technology capabilities increased the exchange of information about technology preferences across the industry, creating a momentum for the adoption of the IEEE 802.11 family of standards by key industry players and resulting in a stronger industry position to leverage a change in operational rules of the 5 GHz band at the global level.

6.3 The Process of Private Rule-Making in the 5 GHz Band

In the late 1990s, the industry for Wireless LANs remained highly diversified in both economic preferences for harvesting different frequency bands (2.4 GHz, 5 GHz) as well as in the distribution of technology capabilities for different standards such as IEEE 802.11, HomeRF or HIPERLAN. However, towards the late 1990s, standardisation work in the IEEE and in ETSI revealed key benefits and limitations of each technology configuration, which prevented them from establishing a strong market presence, similar to the Ethernet standard in the market for wired LANs. The core issue was that wireless LANs using spread spectrum technologies – such as IEEE 802.11 or HomeRF – were cheaper to produce, but, because of the non-interference and non-protected conditions they were operating under in the 2.4 GHz band, could not deliver the higher data transfer rates achieved by wired LANs based on the Ethernet standard. Conversely, wireless LANs using time division technologies – such as HIPERLAN – were considerably more costly to produce but, because they were the only technologies operating in the 5 GHz band, could have higher rates of use as well as de facto exclusivity in the band, enabling higher data transmission rates. Subsequently, the ideal scenario for a standard to take the lead in the market would be to either change rules of access in order to secure de facto exclusivity in the resource, similar to the 5 GHz and 17 GHz bands for HIPERLAN in the CEPT, or to change rules of use during the standardisation process, in order to secure technology exclusivity in harvesting the resource and, implicitly, a strong position in the market.

6.3.1 Negotiating Rules of Management and Exclusion

In the late 1990s, industry actors active in the wireless LAN market were pursuing a combination of standardisation strategies in collaborative, rather than competitive, arrangements. The involvement of the telecommunications companies changed dynamics in the standardisation process from competition to collaboration because:

> "[…] telecommunications companies have a long tradition of fighting for their rights and tend to allocate ample funding to defend their cases. Computer companies, however, operate with much lower margins and typically allocate lower budgets to standardisation efforts" (Lemstra et al 2009: 113).

Two strategies were adopted by a number of key actors participating in the standardisation of WLANs. First, the practice of dual membership in the IEEE and ETSI (Lavie, Lechner and Singh 2012), with or without voting rights in the Working Groups, strengthened information exchanges about basic technology specifications of the standards, achieving higher levels of consensus than possible under the formal majority rules established in these associations. Second, the creation of a WLAN family of standards that would integrate technology capabilities developed in both IEEE 802.11 and in ETSI BRAN (*Table 6.4*). Third, the establishment of a private certification body to approve interoperability of systems and quality of equipment, as a form of self-monitoring. These arrangements gave the WLAN industry considerable leverage to negotiate a rule change in the global allocation of the lower 5 GHz band in favour of primary use for mobile communications (WLANs) at WRC-03.

The creation of the HomeRF consortium in 1997, using a combined method of IEEE 802.11 frequency hopping spread spectrum and DECT time division access technology, gave a lead to HomeRF equipment in the WLAN market in the United States. This position determined some members of the HomeRF Consortium to negotiate a change of rules of access onto the 2.4 GHz band in favour of wideband frequency hopping, in order to secure greater transfer rates (wideband) and effective exclusivity (frequency hopping) in the 2.4 GHz band in the United States. This strategy was perceived to enable new products into the marketplace, with more competitive data transfer rates of 10Mb/s – compared with only 2Mb/s for initial HomeRF equipment, and to allow the consortium to move from the home market to the business market (Negus and Petrick 2009: 49).

The strategy of industry actors in ETSI and IEEE 802.11 was different than the one pursued by the HomeRF Consortium in the late 1990s. Similar to the previous case study presented in this thesis (*Chapter 5*), industry actors participating in the standardisation of ETSI HIPERLAN and in the standardisation of IEEE 802.11 altered their strategies to integrate, rather than exclude, variants of WLANs in the wider mobile communications infrastructure and to coordinate this standardisation activity across the two associations.

Following the limited impact of ETSI HIPERLAN 1 on the development of new high capacity WLANs for the 5 GHz band in Europe, a new project – entitled HIPERLAN 2 – was set up in ETSI Broadband Radio Access Networks (ETSI BRAN) in April 1997. HIPERLAN 2 differed from HIPERLAN 1 in two ways. First, it was promoted by both mobile telecommunications industry (Ericsson, Nokia, Telia) and computing industry (Dell, Bosch). Second, and partly because it was promoted by the mobile communications industry, it was interlinked and integrated in the wider infrastructure of cellular systems in order limit disruption between the two technologies (revisit *Chapter 6*). The decision to interlink the two systems is based on the gradual development of technology capabilities in wireless local area networking by the mobile communications industry. For instance, by the late 1990s, both Ericsson and Nokia were promoting Bluetooth as a wireless local area technology that would compete with other local area networks with low data capacity, including the original IEEE 802.11 (Haartsen 2000)[182]. Also, Nokia was actively engaged in the development of 3G-WLAN interworking at the radio level, which redefined the two technologies – i.e. wide area cellular networks and local area networks – as complementary rather than exclusive technologies (Ahmavaara et al 2003). This approach, encouraged by the telecommunications industry involved in the development of WLANs, modified private actor strategies from standardising with the aim to exclude certain technologies to standardising with the aim to integrate certain technologies[183].

182 Six founding members set up the Bluetooth Consortium in May 1998: Ericsson, Intel, IBM, Nokia and Toshiba.

183 Another way of thinking about this shift in industry strategies is to consider the pressures of short-term competition between specifications for the same technology (e.g. HomeRF versus IEEE 802.11 as WLAN standard) and long-term competition between specifications for different systems (e.g. wide area mobile cellular communications systems versus local area networks).

The decision to interlink wide area and local area network specifications was coupled with a strategy to integrate variants of WLAN standards with different performance characteristics by aligning, as much as possible, the standardisation work in ETSI BRAN (on HIPERLAN 2) and in IEEE 802.11. In the late 1990s, Lucent Technologies, who received the development of radio communication work from NCR following the 1996 AT&T trivestiture (Jakobs et al 2011: 147), actively carried out this strategy by coordinating the standardisation process in both IEEE 802.11 and ETSI BRAN. Although there was no formal agreement of cooperation between ETSI BRAN and IEEE 802.11, the technology exchange that took place between the two industry associations is evidenced in three ways. Participants in the standardisation process had dual membership, with or without voting rights, in the two working groups (Lavie, Lechner and Singh 2012: 8-10). This informal coordination ensured industry alignment on two important configurations of inclusion/exclusion in wireless communications markets: a) alignment on the physical layer (PHY) for high capacity WLANs, which would set a single method of modulating digital signals – OFDM[184], which would inevitably affect the rate of use of the radio resource for other unlicensed participants, and b) alignment on the radio resource – 5 GHz – on which high capacity WLANs can be deployed and potentially harmonised at international level.

The IEEE 802.11 Working Group spearheaded the alignment process on the technology specifications for high capacity WLANs. From 1997 to 1999, the IEEE 802.11 was working on two projects for high capacity WLANs. One was to be deployed in the 2.4 GHz band, with a capacity of up to 10Mb/s. This standard – entitled IEEE 802.11b – was envisioned as closest to the original proposal made by NCR/Lucent Technologies in the early 1990s. The main aim of the standard was to be based on existing direct sequence spread spectrum technology, to be affordable and quick to produce, in order to enter the market prior to any evolutions of the HomeRF standard, which maintained a data transfer rate of 2Mb/s. Following an agreement between Lucent Technologies and Apple to supply WLAN chips based on the IEEE 802.11b standard for 2.4 GHz band in 1998, the IEEE 802.11b standard was successfully rolled over into the market with a considerable data capacity advantage (*Table 6.4*). As Negus and Petrick (2009) noted:

[184] OFDM is a digital modulation technique using orthogonal multicarrier technology, which splits the signal across different narrowband channels. It is not a spread spectrum technology.

> "[…] during 2000 the price gap between the two technologies [IEEE 802.11 and HomeRF] narrowed considerably and 802.11b achieved widespread adoption including in the consumer market [which was dominated by HomeRF]. Because the competitive 10Mb/s HomeRF products did not become commercially available until mid-2001, by the end of 2001, 802.11b products took over the entire WLAN market" (Negus and Petrick 2009: 48).

However, in conjunction with the development of medium capacity[185] IEEE 802.11b for the 2.4 GHz band, the Working Group coordinated with ETSI BRAN for the development of a high capacity standard similar to HIPERLAN 2, which could achieve up to 54 Mb/s in the 5 GHz band across the CEPT (*Table 6.4*).

Table 6.4 Main WLAN Standards of Second Generation

Standard	Modulation	Data Rate	Main Industry Developers
IEEE 802.11b	DSSS	Up to 11 Mb/s in 2.4 GHz	Lucent, 3Com,Nokia, Symbols, Aironet, Intersil
IEEE 802.11a	OFDM	Up to 54 Mb/s in 5 GHz	Lucent, 3Com,Nokia, Symbols, Aironet, Intersil
HomeRF	FHSS (with DECT)	Up to 10 Mb/s in 2.4 GHz	Proxim, Intel, Siemens, Motorola, Philips
Bluetooth	FHSS	Up to 2 Mb/s in 2.4 GHz	Ericsson, Intel, IBM, Nokia, Toshiba
HIPERLAN 2	OFDM	Up to 54 Mb/s in 5 GHz	Bosch, Nokia, Ericsson, Dell

Source: Lemstra et al (2009), Pareek (2006)

The position taken in the IEEE 802.11 Working Group in 1997 was to propose the opening of the lower 5 GHz band in the United States under similar conditions to those adopted by the CEPT for the harmonised introduction of HIPERLAN in the lower 5 GHz band. If similar rules of access to ETSI HIPERLAN in 5 GHz band were replicated in the United States, allowing for technologies other than spread spectrum, with their respective power limits, to operate in the band, then higher data capacity systems for local area networks could be deployed simultaneously for the two markets – Europe and the United States – with de facto primacy of access. Thus, in January 1997, the FFC opened the lower 5 GHz band under a set of rules for the Unlicensed National Information Infrastructure (U-NII) similar to HIPERLAN (FCC 1997). A year later, ETSI BRAN and IEEE 802.11 were putting forward high capacity standards based on

[185] The data transfer rate in the 2.4 GHz band was limited by the power levels applications operating in the ISM bands had to adhere to. Revisit *Section 6.2.2*.

the OFDM modulation technology, which as Negus and Petrick noted, is not a spread spectrum technology (Negus and Petrick 2009: 45).

Although the HIPERLAN standard and the IEEE 802.11a standard at 54Mb/s did not have the same media access technology, they were aligned enough to reconfigure the fragmented WLAN market around the development of two types of technology – spread spectrum for low data rates and multiplexing for high data rates – and around two frequency bands – 2.4 GHz band and 5 GHz band – both unlicensed but with considerably different rules of access specific to the two technologies. In addition, because IEEE 802.11 – at higher data rates of 11 Mb/s for the 2.4 GHz band and 54Mb/s for the 5 GHz band – were rolled out quickly in the market, they achieved strong market positions by the mid 2000s. The next sections look at how the minimum alignment between the standardisation process in ETSI and in IEEE 802.11 contributed to the allocation of half of the 5 GHz band to WLANs on a primary basis at WRC-03, changing rules of access onto the 5 GHz band at global level for a technology that, at least theoretically, requires no protection from interference. Similarly, the next sections show how this industry alignment, strengthened by the integration of local area and wide area cellular networks, led to a change in rules of use of the 2.4 GHz and 5 GHz bands around a single family of WLAN standards – IEEE 802.11 – with a private certification procedure in the Wireless Ethernet Compatibility Alliance (WECA), which marketed equipment compatible with the IEEE 802.11 family of standards under the brand Wi-Fi.

6.3.2 Negotiating Rules of Access

In 2003, the World Radiocommunications Conference (WRC-03) allocated 455 MHz of spectrum in the 5 GHz band to international use by WLAN systems on a primary/co-primary basis: a) indoor WLAN use in the 5,150-5,250 MHz band (100 MHz) and b) indoor/outdoor WLAN use in the 5,250-5,350 MHz band (355 MHz) (Resolution 229, WRC-03). This allocation of WLANs to half of the 5 GHz band sealed the rules of access already established in the lower 5 GHz bands for high capacity systems in the United States and across Europe and, essentially, extended them at the global level.

The position of the industry in driving this global allocation, through regulatory alignment at the regional level, is important to investigate for two reasons. First, there is an inherent contradiction between WLANs as non-protected and non-interference allocations to public commons such as the ISM bands and WLANs that, by virtue of their primary or co-primary status in international allocations, become private commons, themselves protected against interference by other services. Second, there is an inherent contradiction between WLANs with international allocations in one frequency pool (5 GHz band) and WLANs without international allocations in another frequency pool (2.4 GHz band). As in the previous cases analysed in this thesis, differences in operational rules of access in frequency pool, such as the 2.4 GHz and 5 GHz bands, are given by configurations embedded in the technology systems deployed in order to harvest the resource for different markets. Thus, the main point of difference between WLANs standardised for the 2.4 GHz band and WLANs standardised for the 5 GHz band is the data transfer capacity rate, which is considerably higher in the latter type of WLANs. Because high data transfer rates employed in interactive multimedia services, for instance, could not be produced at affordable levels, using low power and low emission spread spectrum, other technologies – i.e. OFDM – were used, which are not spread spectrum. Because of this technology configuration, however, rules of access and use also have to be altered.

In the late 1990s, OFDM was, essentially, a new generation of modulation techniques. Its main use, at the time, was in digital broadcasting (DVB-T) and, a few years later, in fourth generation radio access interfaces for IMT-2000 and IMT-Advanced systems such as Long Term Evolution (LTE). As a frequency division multiplexing technology, OFDM requires multiple frequencies to which it assigns narrow signals, a fundamental difference from spread spectrum techniques, such as direct sequence (DSSS), which spread the signal in a single frequency. Thus, OFDM produces considerable more interference than spread spectrum and, conversely, requires more protection from interference than spread spectrum techniques, which explains the need to secure WLAN allocations in the 5 GHz band and not the 2.4 GHz band at international level. Lemstra, Hayes and van der Steen (2009) explain why securing primary status for HIPERLAN specifications was important for industry developers with investments in this technology:

> "[…] European Administrations were unhappy with the prospect that an incumbent user that received primary status at a WRC, on the promise that they could comply with the rules stated for HIPERLANs in the 5 GHz band, would subsequently be forced to reduce the permitted power for the

> HIPERLAN devices from 1000 mW without limits to 200 mW, and to indoor use. By requesting and obtaining an allocation at primary level for WLANs through the WRC, non-interference with existing WLANs would have to be assured for all new applications in that frequency band" (Lemstra et al 2009: 112).

The position put forward by Lemstra et al (2009), which was promoted by industry members in conjunction with the CEPT and the FCC (Negus and Petrick 2009: 37), describes the process by which changes in one aspect of the specifications of a technology or standard affect, as in the case of WLANs for 5 GHz, operational rules of access to frequency bands deploying, in theory, the same system. The rules of access adopted, at global level, for the 5 GHz band also reflect how two systems delivering the same service – i.e. mobile communications in wireless local area networks – can be managed as a public common based on non-protection from interference (spread spectrum) or as a private common based on primary protection from interference (frequency multiplexing).

6.3.3 Negotiating Rules of Use

By securing primary access to the 5 GHz frequency bands at global level, the WLAN industry had secured de facto exclusivity on the band. This allowed for a considerably more stable and secure frequency environment in which WLANs could develop without the threat of interference by other devices using the band.

A further step to prevent interference from other non-IEEE 802.11 devices that could populate the band, by simply abiding to power levels of use, was to create a certification association that would act as a self-monitoring and self-promotion mechanism. Thus, in August 1999, only a few months prior to the approval of the IEEE 802.11 standard for the 2.4 GHz band (IEEE 802.11b) and for the 5 GHz band (IEEE 802.11a), six of the WLAN industry representatives that took part in the IEEE 802.11 Work Group set up the Wireless Ethernet Compatibility Alliance (WECA), a not-for-profit industry association with responsibility to certify WLAN equipment based on the IEEE 802.11 family of standards, through a process of interoperability compliance testing (Wi-Fi Alliance 1999).

In short, WECA became an informal association that monitored industry compliance with the standard, ensuring that power levels and other emissions specified in the IEEE 802.11 family of standards are abided by, ensuring protection from interference. A seal of approval from WECA signified a seal of safe use of the public common at 2.4 GHz as well as the private common at 5 GHz. In 2002, a year before WRC-03, and with over 100 industry members, WECA changes its name to the Wi-Fi Alliance, with responsibility to brand every equipment interoperable and compliant with the IEEE 802.11 standard as Wi-Fi. Thus, in this process, the Wi-Fi Alliance became a self-monitoring association that ensured conformance with given parameters of use of the radio resource, as agreed by the industry in conjunction with public regulators. The monitoring role of the Wi-Fi Alliance ensured that the set of common rules of the radio resource were applied in the regional public commons established at 2.4 GHz and the international private commons established at 5 GHz, minimising the public process of reporting interference from a potentially "harmful" device.

6.4 The Impact of Private Association on the Choice of Property System

This section discusses the relationship between the organisation of the electronic communications industry and the development of operational and collective choice rights in the 2.4 GHz band and the 5 GHz band. It pays particular attention to the way in which private coordination between the information technology and the mobile communications industry led to an alignment of economic interests for the emergence of IEEE 802.11 as the de facto standard for wireless local area networks (WLANs) and for its integration with wide area mobile cellular communications systems. It discusses the extent to which this private coordination shaped industry preferences for operational rules based on conditioned common use and primary access as specified in the IEEE 802.11a/ ETSI HIPERLAN 2 configurations for the 5 GHz band.

6.4.1 The Nature of Private Association

In the 1990s, the emergence of multiple standards for wireless local area networks (WLANs) revealed low level of industry coordination for the deployment of this technology. However, towards the late 1990s, standardisation work in the IEEE and in ETSI revealed key benefits and limitations of each technology configurations and, most importantly, of combining elements of these technologies as well as of integrating them with the existing mobile telecommunications infrastructure as inclusive, rather than as exclusive, systems. Two important steps, which were discussed above, were taken in this case. First, interworking specifications between wide area mobile cellular communications networks, as specified by 3GPP, and wireless local area networks, as specified by IEEE 802.11 and ETSI BRAN, was implemented. In 2003, the 3GPP proposed this approach and reported:

> "3GPP has […] taken the initiative to develop a cellular-WLAN interworking architecture as an add-on to the existing 3GPP cellular system specifications […]. The main driver is to enable 3GPP system operators to provide public WLAN access as an integral component of their total service offering to their subscribers" (Ahmavaara et al 2003: 74).

The second step towards coordination was the agreement on a single method of modulating digital signals for wideband WLANs, based on OFDM, in both IEEE 802.11 and ETSI BRAN. The alignment of the computing and mobile communications industry on OFDM, as the single choice of specification for modulating digital signals, shaped the industry preference in favour of stricter rules of access for wideband WLANs in the 5 GHz band. Because OFDM was not a spread spectrum technology, it conditioned protection from interference rather than, as in the case spread spectrum, non-protection and non-interference. Noting on the role of the Wi-Fi Alliance in this allocation of the 5 GHz band for wireless mobile services on a primary basis, Lemstra, Hayes and van der Steen (2009) noted that:

> "Lucent Techologies, through Vic Hayes, understood, on the one hand, the importance of this allocation for the future of Wi-Fi and, on the other hand, the significant effort it would take to coalesce the industry to make this allocation come true. […] At the beginning of 2001, Hayes successfully started a rally in the one-year old Wi-Fi Alliance to establish a committee with sufficient decision power to be able to act quickly in response to the events that would develop at the regulatory agencies […]" (Lemstra, Hayes and van der Steen 2009: 112-113).

This depiction of events reveals the relationship between the organisation of the industry, the choice of a particular technology system and the configuration of operational rules of access and use in a frequency pool. It is indicative of the reasons behind the different approach in the allocation of WLANs in the 2.4 GHz band and in the 5 GHz band, reflecting a particular technology configuration, which would respond to a unified economic interest (i.e. high speed data rates for wireless LANs) and a single technology capability (i.e. OFDM).

6.4.2 The Nature of Property Arrangements in the 2.4 GHz and the 5 GHz Frequency Pools

The difference in the regulation of the 2.4 GHz and the 5 GHz bands reveals important considerations about the relationship between the configuration of industry actors and the property arrangements that result from their organisation. *Table 6.5* provides a summary of the configuration of property arrangements that resulted in the 2.4 GHz and 5 GHz bands for the deployment of WLANs in the early 2000s.

Table 6.5 The Configuration of Property Arrangements in the 2.4 GHz Regional Pool and the 5 GHz Frequency Pool for the Deployment of WLANs

Property Right		**Property Arrangements in the 2.4 GHz band and the 5 GHz band for WLANs**
Operational Rights	*Access*	Rights to access the 2.4 GHz band is open to low emission devices – i.e. public common – with minimum conditions of non-protection and non-interference (ISM services).
		Rights to access the lower 5 GHz band is given on a co-primary basis to mobile communications services at global level (WRC-03).
	Use	In both 2.4 GHz and 5 GHz, rights of use are conditioned on power and interference levels. They are given by the technology configuration of the equipment, based on spectrum requirement: a) spread spectrum (accepts interference), b) orthogonal frequency division (needs protection from interference).
Collective Choice Rights	*Management*	Limited coordination in 2.4 GHz band at initial stage.
		Increased coordination between industry associations representing information technology and telecommunications industry – i.e. IEEE 802.11 and ETSI BRAN – for 2.4 GHz and 5 GHz in second generation WLANs. Dual membership in IEEE 802.11 and ETSI BRAN, information exchange on system configurations before setting operational rules for the 5 GHz band (WRC-03). Technology co-existence, rather than technology excludability, between mobile cellular communications systems for wide areas (3GPP) and local areas (ETSI BRAN and IEEE 802.11).
		Mutual monitoring through certification of quality and interoperability in Wi-Fi Alliance.
	Exclusion	No right to exclude in 2.4 GHz band (ISM services). Right to exclude in 5 GHz band derived from co-primary status for WLANs (WRC-03).

At the operational level, the main difference between the two configurations of property arrangements rests with the higher level of exclusive access provided to WLANs in the 5 GHz band, as derived from the allocation of mobile communications on a primary basis at the WRC-03. In short, this changed the status of WLANs from non-protected (in the 2.4 GHz band) to protected (in the 5 GHz band), informed by the initial allocations to HIPERLANs in the lower 5 GHz band in the CEPT.

Similar to the previous case study (*Chapter 5*), there are three collective choice rules that the industry, organised in IEEE 802.11 and in ETSI BRAN, established in order to align preferences for this "protected" allocation for WLANs of second generation in the

5 GHz band. First, participants in IEEE 802.11 and in ETSI BRAN established informal mechanisms of information exchange on the main configurations of the two standards being developed, simultaneously, for the 2.4 GHz band and the 5 GHz band. Second, the decision to create a family of standards that would integrate, rather than exclude, standards with different data transfer capabilities and different technology configurations under the aegis of IEEE 802.11 – direct sequence spread spectrum (DSSS) for the 2.4 GHz band on a non-protected basis, as required in ISM bands and orthogonal frequency division multiplexing (OFDM) for the 5 GHz band on a protected basis. In creating standards for high data transfers in WLANs, based on the minimum harmonisation of the physical layers in IEEE 802.11 and ETSI HIPERLAN 2, the information technology and the telecommunications industry could commit to the development of the market for this equipment and could leverage an allocation on a protected primary basis at WRC-03. Third, the role of the Wi-Fi Alliance in certifying and branding products, which met the specifications of the IEEE 802.11 family of standards, created a mechanism of monitoring and developing the market.

6.5 Conclusions

This case has traced the process leading to the definition of different operational rules for the deployment of wireless local area networks (WLANs) in the 2.4 GHz band and in the 5 GHz band. The case suggests that industry actors with asymmetric preferences for economic activity in different bands of the radio resource, coupled with a relatively symmetric distribution of technology capabilities among them, will find it difficult to arrange private cooperation in order to harvest a common pool resource more efficiently. This was the case of the information technology industry in the early 1990s, when their heterogeneous preferences for the deployment of competing technologies in different bands prevented them from arriving to the definition of a standard in the IEEE 802.11 working group and, subsequently, from driving down the cost of manufacturing WLAN equipment to be deployed in the 2.4 GHz band. The case is particularly relevant because, as it is revealed, a public actor had opened the 2.4 GHz band for technologies upon which WLANs could be and, indeed, was developed. The case is also relevant because it uncovers the configuration of group attributes – i.e. heterogeneity of interests and homogeneity of capabilities – that appears to block, rather than facilitate, coordination for harvesting the radio resource, even in conditions when the resource is already regulated as a public common, i.e. conditioned common use and open access.

However, the gradual diversification of the electronic communications market, with the particular entry of mobile telecommunications developers in the provision of data services, changed this initial configuration of interests, gradually, over the 1990s. A new configuration of interests and capabilities was taking shape in IEEE 802.11 and in ETSI BRAN, which revealed a diversification of interests for two different bands (2.4 GHz and 5 GHz) as well as a diversification of technology capabilities based on information technologies and mobile communications systems. This situation of increased diversification, coupled with pressures from the HomeRF Consortium to change regulations in the 2.4 GHz via the public actor in the United States, increased the level of communication between IEEE 802.11 and ETSI BRAN, leading to an alignment on the basic specifications – OFDM in the physical layer – for high capacity WLANs. The information exchange between the two associations – IEEE 802.11 and ETSI BRAN – facilitated an alignment of technology preferences for inclusive rather than exclusive technologies based on a family of standard in IEEE 802.11. These measures, coupled with the establishment of the Wi-Fi Alliance as a private certification mechanism, provided the mobile telecommunications and the information technology industry with considerable leverage to change the allocation of the 5 GHz band to mobile communications (also WLANs), on a co-primary basis, at the global level. By changing the allocation status of WLANs to primary services at the international level, the electronic communications industry increased the level of de facto excludability of these services in the designated bands, creating a private common in the 5 GHz band, based on conditioned common use and exclusive access.

Overall, this case contributes to our understanding of dynamics of coordination inside a transnational common pool in two ways. Similar to the previous case study (*Chapter 5*), it reveals that heterogeneity of interests and capabilities does not inhibit coordination. On the contrary, it facilitates communication and information exchanges between industry parties and industry associations, which results in greater coordination to change operational rules of access – i.e. greater protection from interference by other services as a form of de facto exclusivity – in the 5 GHz band for WLANs.

Chapter 7. Conclusion

This thesis has set out to inquire into the determinants of property arrangements in transnational common pool resources. It has focused on explaining variation in property arrangements in a single transnational common pool resource – i.e. the electromagnetic radio spectrum – across some of the frequency bands the radio resource is divided into and across time. There are three theoretical assumptions that informed the question and design of this study. These assumptions have been challenged throughout this study. The first assumption is that public entities are the central actors who initiate and define the regulation of transnational commons in order to overcome problems of collective action that arise in this type of resource. The second assumption is that private entities cannot successfully organise to define stable and comprehensive rules to access and use a transnational common such as the radio spectrum, especially when their economic interests and technology capabilities are highly diversified. The third assumption is that private entities wishing to extract economic value from a common resource have a preference for individual exclusive property rights in order to secure single use and exclusive access to the resource. The radio spectrum[186] has provided good ground to test these theoretical assumptions. On the one hand, public entities manage the radio resource on their sovereign territory and coordinate it, internationally, on principles of non-interference and interconnection. On the other hand, private entities manage the radio resource by utilising it as input in the production of other common goods[187] of a transnational nature, such as mobile communications.

So, who truly runs the radio commons?

This thesis makes three key findings about the regulation of the radio resource as a type of transnational common pool resource. First, this research finds that private actors, such as service operators and equipment manufacturers, are very active in defining rules of operation in the radio resource, by negotiating technology arrangements with

[186] As previously explained, in supra note 6, this thesis looks only at the regulation of the commercial electromagnetic radio spectrum rather than the entire radio spectrum, most of which is used for public defence, scientific, etc purposes.

[187] As previously explained, in supra note 7, this thesis adopts the definition of "transnational common goods" put forward by Holzinger (2008). "Common goods will be used as a synonym for all goods that are not purely private. […] Common goods are defined by the presence of externalities". As Holzinger (2008) noted, "this definition has the advantage of capturing a number of different notions of goods such as pure public goods, club goods, CPRs, congestibles or network goods" (Holzinger 2008: 28).

embedded configurations of access and use of a given frequency band. These negotiations take place in industry associations at transnational level, which transcend rule-making at the domestic level and interact with regional or international polities – such as the European Union (EU) or the International Telecommunications Union (ITU) – in a polycentric system of governance comprising both public and private entities with different responsibilities for defining, monitoring and enforcing rules of access and rules of use in the radio resource (*Figure 7.1*).

Figure 7.1 Matrix of Main Findings by Case Study

		900 MHz Case I	**1.9-2.1 GHz** Case II	**800 MHz** Case III	**2.4 GHz** Case IV	**5 GHz** Case IV
Public Actor	*Formal Competence*		✔	✔		✔
	Technology Preference		✔			
Private Actors	*Diversity of Interests*			✔	✔	✔
	Diversity of Capabilities		✔	✔		✔
Private Cooperation Operational Rules	*Expected*	high	high	low	low	low
	Actual	high	high	high	low	high
Private Cooperation Collective Choice Rules	*Expected*	high	high	low	low	low
	Actual	low	low	high	low	high
Property Arrangements	*Individual exclusive*	✔	✔		✔	
	Common exclusive			✔		✔

Second, this research finds that private actors can organise to solve distributional problems of collective action in transnational frequency bands, even in conditions of highly diversified economic interests and technology capabilities. Far from leading to collective inaction, the complexity of this situation makes industry actors exchange more technical information and engage in more comprehensive mutual monitoring, before setting operational rules of access and use in a given frequency band.

Third, this research finds that private actors interested in extracting economic value from a given frequency band are not primarily concerned with the individualisation of a property right but with the excludability of the right in the radio resource. Far from exhibiting a unique preference for individual exclusive property, private actors with diversified economic interests and technology capabilities can opt for flexible rights of use as long as their right of access is exclusively ensured in a given frequency band.

These findings speak to three specialist literatures in the field of public policy. The evidence about the role of private actors as rule makers in the organisation of the radio spectrum, even in conditions of diverse interests and capabilities, speaks to the literature on collective action and, specifically, the collective protection or provision of transnational common goods. The evidence about the nature of cooperation in industry associations[188], organised to negotiate and define rights of use and rights of access onto the radio resource, speaks to the literature on transnational private regulation. The evidence about the interaction between this associative mode of governance and other polities speaks to the wider governance literature and, specifically, to the literature exploring governance in the European Union (EU).

The following sections provide a detailed analysis of this evidence and its contribution to the specialist literature. Before providing a more detailed analysis of this evidence, it is important to recall that, by design, this research has been conducted as a theory testing exercise with a small n sample in order to verify determinants (i.e. public or private actors) of a type of outcome (i.e. property arrangements) and the causal mechanisms in this process. Thus, the main purpose of these findings is to enrich existing theories concerned with the provision or protection of transnational common goods.

7.1 Collective Action in Transnational Commons

This research has been designed as an inquiry into the nature of collective action for managing the radio spectrum as a transnational common pool resource and for providing mobile communication systems as transnational common goods, benefiting from the use of radio frequencies as input to their production. The following sections discuss the findings of this research in relation to four questions in the literature on collective action in transnational commons. First, whether problems of collective action recognised in the protection and provision of common goods apply to the management

[188] This thesis adopts a wide definition of industry associations, which includes professional bodies, certification bodies and standardisation bodies belonging to a single industry sector, (e.g. electronic communications).

of the radio spectrum (Holzinger 2008, Ostrom 2003). Second, whether the need for external intervention in the provision of stable institutions to regulate access and use of common pool resources is confirmed in the case of the radio spectrum (Hardin 1968, Hardin 1998, Ostrom 2010, Pennington 2012). Third, whether, in the absence of external intervention, the diverse distribution of private interests and capabilities is more likely to inhibit the collective regulation of a common pool resource such as the radio spectrum (Libecap 1995, Martin 1995, Varughese and Ostrom 2001). Fourth, whether private actors are more likely to prefer institutional outcomes that resemble individual exclusive property when managing a common pool resource such as the radio spectrum, in order to maximise individual withdrawal rates from the resource (Faulhaber and Farber 2003).

7.1.1 Collective Action Problems in Transnational Commons

This thesis has demonstrated that, in a state of nature, the radio spectrum is a common pool resource exposed to problems of collective action resulting from the competitive extraction of frequency units by resource users (i.e. rivalry of consumption) as well as from the difficulty to exclude beneficiaries that would not contribute to maintaining the resource or to internalising the costs of interference as a negative externality produced during the use of the radio resource (i.e. non-excludability). This thesis has also demonstrated that, due to the borderless nature of electromagnetic radio waves, problems of collective action in the radio resource are uploaded to the international level, where several types of conflict are revealed, including complementarity conflicts which affect rival use (Case I, Case II, Case III), excludable conflicts which affect access (Case I, Case III, Case IV), consumptive conflicts which affect the rate of use (Case III), as well as negative externality conflicts which affect interference levels (Case IV).

This finding indicates that problems of collective action in transnational commons are more diverse than defection problems, which result in the “tragedy of the commons” (Hardin 1968). Using the typology of problems of collective action provided by Holzinger (2008: 154-159), the radio spectrum exhibits three types of problems at the transnational level. First, defection problems that have been solved by both public and private actors during the allocation of international frequency bands to communication services rather than to sovereign states, together with the adoption of the principles of minimum intercommunication and non-interference (revisit *Chapter 1*). Second, distributional problems that concern the degree of rivalry and excludability in a given radio frequency pool and that have been witnessed, to different levels, in all of the cases put forward in this thesis. As previously noted, distributional problems concern "partial conflict over the valuation of outcomes" (i.e. which degree of rivalry and excludability in a frequency pool) rather than conflict over a strategy to achieve a single equilibrium (i.e. whether to collaborate or not to collaborate in the management of a frequency pool) (Holzinger 2008: 155, Martin 1995). Third, disagreement problems that concern the degree of rivalry within a given radio frequency pool and that have been witnessed in some of the cases put forward in this thesis (*Case I* and *Case II*). These disagreement problems, which have been previously referred to as "battles of the systems"[189] in studies of telecommunication standardisation (Schmidt and Werle 1998), do not concern the collective welfare of a common resource. Interestingly, in the radio spectrum, distributional problems concerning the degree of rivalry and excludability in a given frequency pool and disagreement problems concerning rivalry over the system to be used in order to extract value from a frequency pool are generally resolved simultaneously, due to the technology-dependent nature of this resource (Wormbs 2011). This explains the eventual creation of complex standards (e.g. GSM in Case I, UMTS in Case II) or complex systems (e.g. IMT-2000 in Case II, LTE/SAE in Case III) that are aimed to solve both relative (i.e. distributional, disagreement) and absolute conflict (i.e. collaboration).

These findings make two contributions to the growing literature concerned with problems of collective action in transnational common goods (Abbott 2012, Héritier 2002, Holzinger 2008, Hoffman 2013, Ostrom 2009). First, they confirm that defection problems between rational actors, which can lead to tragedies of the commons, are not endemic to all common resources (Bromley et al 1992, Ostrom 1990) and have, potentially, been overstated when considering who can solve them, at what decision-making level and by what institutional means (Ostrom 1998, Udehn 1993). Second, they reveal the predominance of distributional and disagreement problems in the radio spectrum, as an example of a transnational common good where there is considerable

[189] As Werle (2001) noted, they are a variant of the "battle of the sexes" and refer to conflict over telecommunications standards between companies that sell competing systems.

conflict over which property arrangement should prevail (i.e. what degree of rivalry and excludability), but there is limited conflict over whether there should be a property arrangement aimed to achieve the stable and sustainable extraction of the radio resource without harmful interference or congestion. Libecap (1995) confirmed this point of view, that "in the absence of serious disputes over the aggregate gains […] of assigning or modifying property rights to an open-access resource, the problem of collective action is one of distribution, achieving agreement on the individual share of resource rents that are implicit in the assignment of property rights" (Libecap 1995: 165).

In sum, the current thesis reveals that the nature of collective action problems in common goods and, specifically, in transnational common goods needs considerable attention before prescribing policy solution that might, in fact, respond to other problems. Dealing with different types of conflict, at different decision-making levels, and by different institutional means, has been recently identified in the regulation of the climate (Hoffman 2013) and has been promoted by "building blocks" approaches, which recognise the importance of dealing with functional policy issues in the regulation of global public goods (Falkner et al 2010). The current study confirms that a "building blocks" model – which, in the case of climate change, advocates dealing with different problems such as adaptation, mitigation or technology transfers by different institutional means (Falkner et al 2010: 259) – can also be witnessed in the management of the radio spectrum, where defection problems are dealt with by international regulation and distributional or disagreement problems are dealt with separately, by transnational regulation, originating from private actors. Thus, the current study confirms that these models can potentially become more effective at matching the nature of the collective action problem to the institutional arrangement that best responds to the problem, without framing it as a global defection problem, which inevitably leads to the underprovision or underprotection of a transnational common good.

7.1.2 The Need for External Regulation of Transnational Commons

One of the central claims of the collective action literature initiated by G. Hardin (1968) is that only an external entity with governing capacity can regulate the resource in order to avoid a tragedy of the commons. This proposal is specifically linked to the premise that, in the absence of exclusion mechanisms imposed by an external regulator (Hardin 1998), individual users will extract as much of the resource as possible to the point of congestion or depletion (Pennington 2012: 23).

The current study disproves this claim on two grounds. The requirement for an external authority to solve problems of collective action in the radio spectrum does not verify when analysing the origin of the international regulation of the radio resource (designed to resolve defection problems) or when analysing the origin of the transnational regulation of the radio resource (designed to resolve distributional and, at times, disagreement problems). First, both public and private entities coordinated their strategies to define the Radio Regulations (ITU) in the absence of an international body to impose the administration of this resource (revisit *Chapter 1*). Second, individual users initiated and negotiated rules for solving distributional problems about the degree of rivalry and excludability in a given frequency band in the absence of an external body with competence to propose such rules (*Case I*) as well as, most interestingly, in the presence of an external body with competence to do so (*Case II*, *Case III*, *Case IV* (5GHz)). Specifically, the case studies analysed in this thesis show little correlation between the presence of the European Commission – as an external entity with formal competence to initiate the transnational regulation of a radio frequency band in the geography of interest (i.e. the European region) – and the ability or willingness of individual users to engage in transnational private cooperation over rules to access and use a given frequency pool (revisit *Figure 7.1*).

These findings make two contributions to the collective action literature. First, they confirm that the classic assumption about the inability of rational individuals to overcome dilemmas of protection and provision of common goods has been overstated as a universal principle of economic behaviour (Ostrom 2008). As Ostrom noted:

> "*The classic models have been used to view those who are involved in a prisoner's dilemma game or other social dilemmas as always trapped in the situation without capabilities to change the structure themselves. This analytical step was a retrogressive step in the theories used to analyse the human condition. Whether or not the individuals, who are in a situation, have capacities to transform the external variables affecting their own situation varies dramatically from one situation to the next. It is an empirical condition that varies from situation to situation rather than a logical universality*" (Ostrom 2010: 649).

Second, these findings align with the growing evidence in the collective action literature that disproves the need for external bodies, such as governments, to "impose a management structure over the [common] resource" (Pennington 2012: 23), under the premise that the circumstances of this social dilemmas will inevitably lead to the underprotection of the common pool or the underprovision of the common goods (Agrawal 2003, Ostrom 1990). For global commons, such as the radio resource, the oceans or the climate, these findings indicate that the presence of an external entity – with capacity to impose rules and regulations onto public entities (i.e. states) or private entities (i.e. firms operating across states) wishing to extract economic value from a common resource – is not a requirement in all situations when the protection of the transnational common is needed. However, the normative implications of this proposition require careful consideration. The findings of this thesis, which highlight the limited need for external intervention in the provision of stable institutions to regulate access and use of the radio resource, do not make claims about the efficiency of this collective regulation over the external regulation of a common resource or the general capacity of individual entities to achieve sustainable collective regulation in all social circumstances related to the protection or provision of common goods. In this case, the sustainability of institutions in transnational radio frequencies refers to their ability to be maintained at the level agreed upon by a user collective, without leading to problems of collective action pertaining to the original issue that the regulation tried to solve, be it a coordination, distributional or disagreement problem of collective action. Thus, the findings put forward in this thesis pertain to showing the non-generalisable character of rational theories of collective action rather than the generalisable character of its alternatives.

7.1.3 The Conditions for Internal Regulation of Transnational Commons

The claim that, under certain circumstances, individual users can initiate, define and redefine operational rules to access and use a transnational common pool, in the absence of an external regulator, brings to question the conditions that might enable or inhibit their ability to solve such problems of collective action. The current study addressed this question by testing the impact of two widely theorised attributes of a user group on their ability to regulate a common pool resource in a sustainable manner (Holzinger 2008, Keohane and Ostrom 1995, Olson 1965). These attributes pertain to the diversity of interests and capabilities within a group of resource users willing to extract economic value from a given resource pool at transnational level (revisit *Chapter 1*). However, a limitation of theoretical expectations regarding the impact of heterogeneity on collective action is that it has led to contradictory findings when analysing the protection or provision of common goods at local and at international level (revisit *Chapter 2*). On the one hand, studies of local commons[190] find that heterogeneity of interests or capabilities inhibits the ability of individuals to define collective rules to operate in a common pool (Martin 1995: 73). On the other hand, studies looking at international common goods[191] find that heterogeneity of capabilities, as a proxy for power in negotiations, can either inhibit individuals to define collective rules to operate in a common if these capabilities are highly dispersed among members of the group (Martin 1995: 75) or can enable individuals to define collective rules to operate in a common if such capabilities are highly concentrated among few members of the group (Martin 1995: 78-79). Thus, the current study has aimed to test the impact of heterogeneity of economic interests and technology capabilities on private cooperation in the regulation of the radio spectrum in order to reveal whether theoretical expectations derived from the analysis of local commons or international common goods apply.

The current study makes two findings on the relationship between these group characteristics and a group's ability to initiate and sustain collective action in the transnational radio spectrum. First, the current study finds that homogeneity of economic interests among a group of resource users might enable them to define operational rules to access and use a frequency pool but might not enable them to safeguard these operational rules with collective choice arrangements. Specifically, in Case I and Case II, private users did not establish comprehensive collective choice rules of management (e.g. ETSI SMG on declaring essential patents in Case II) and rules of exclusion (e.g. entry of Motorola in GSM MoU in Case I), which disrupted operational rules of access and use agreed upon by the group of users (revisit *Figure 7.1*). This finding disproves theoretical expectations in the study of local commons that predict a positive relationship between homogeneity of interests within a group and its ability to

[190] These studies refer to natural common pool resources of a local nature, such as grazing grounds, forests, water basins, which are administered by local communities rather than central administrations belonging to the state.
[191] These studies refer to the protection of common goods such as the climate, the oceans or to the provision of common goods such as tax coordination. They have been primarily concerned with cooperation between states rather than non-state actors.

define and sustain rules to govern a common pool resource (Baland and Platteau 1999, Libecap 1989, Libecap 1995).

Second, the current study finds that heterogeneity of technology capabilities in a large group of resource users, even when combined with heterogeneity of economic interests, does not inhibit the group's ability to define operational rules to access and use a frequency pool. This finding disproves theoretical expectations in the study of local commons that predict a negative relationship between heterogeneity of interests and capabilities within a group and its ability to sustain rules of operation and management in a common pool resource (Libecap 1995, Varughese and Ostrom 2001). This finding also disproves theoretical expectations in the study of international commons that assume a positive relationship between the concentration of capabilities in the hands of a few non-competing members of the group and the ability of the group to define and stabilise rule systems in the commons (Keohane and Ostrom 1995, Krasner 1991, Martin 1995). Surprisingly, in Case III and Case IV (5GHz), private users establish collective choice rules that stabilise their commitments to operational rules of use and access of the frequency pool. This increased level of commitment to operational rules is facilitated by three, otherwise recognised, mechanisms for sustaining operational institutions in the governance of common pool resources (Agrawal 2003, Ostrom 1990: 90-102):

a. Equitable participation in decision making on system design by direct frequency users – i.e. both service operators and system developers (Case III)
b. Information exchange about technology preferences via informal interest associations (WWRF in Case III) or via informal communication venues between formal interest associations (ETSI BRAN and IEEE 802.11 in Case IV (5GHz)).
c. Mutual monitoring of commitments to operational rules during the system design process (NGMN and LTE/SAE Alliance in Case III, Wi-Fi Alliance in Case IV).

These findings carry three implications to the literature exploring the relationship between heterogeneity and collective action in the management of common pool resources. First, this thesis finds a weak relationship between heterogeneity and collective action among private users of a common pool resource. This holds for both heterogeneity of economic interests and heterogeneity of technology capabilities, as well as for the situations, as in Case III and Case IV (5GHz), when heterogeneity of interests is combined with heterogeneity of capabilities in a resource user group. In fact, in Case III and Case IV (5GHz), private users are aware of their situation of internal heterogeneity and, subsequently, engage in the design of more comprehensive rules of management, such as equitable participation in decision making, information exchange and mutual monitoring of commitments to operational rules during the system design process. The situation presented in Case III and Case IV (5GHz) confirms that, at least when distributional problems in the commons are concerned, heterogeneity of interests or capabilities is not an inhibitor of collective action but "a challenge that can be overcome by good institutional design when the interests of those controlling collective choice mechanisms are benefited by investing time and effort to craft better rules" (Varughese and Ostrom 2001: 747). In fact, in Case III and Case IV (5GHz), heterogeneity creates an environment of uncertainty, which appears to drive private actors to invest in mechanisms of information exchange and mutual monitoring in order to secure their commitments to operational rules for the given frequency bands. Thus, the surprising finding of these two cases is that group heterogeneity does not inhibit private cooperation to supply operational rules in the commons (Poteete and Ostrom 2004). On the contrary, it appears that, in these situations, private users devise collective choice rules to ensure and monitor their commitments to operational rules in a given frequency band.

This points at the second implication of these findings for the wider discussion about individual and collective rationality in the use of a common pool resource. In Case III and Case IV (5GHz), private actors interested in harvesting a frequency pool appear to define their economic interests in terms of both relative (i.e. distributional) and absolute (i.e. collaborative) gains (Snidal 1991). In this case, private resource users reveal a more complex motivational structure for their behaviour, which allows them to change the internal structure of incentives within the group (Ostrom 2008, Ostrom 2010). For instance, in Case III, ensuring access to an enlarged frequency pool for the deployment of IMT mobile communication systems appears to take precedence over relative gains concerning individual withdrawal rates from competing communications systems that make up the IMT family of standards. This finding indicates that the analysis of the motivational structure of a group of resource users could be more relevant than the distribution of economic interests or technology capabilities within the group.

However, this thesis shows that, although the distribution of interests or capabilities might not be, per se, a strong indicator of collective action in the management of common pool resources, economic interests and technology capabilities do matter in order to understand the specific design of operational and collective choice rules in the commons. This is the third contribution of the current study to the collective action literature exploring the conditions for internal regulation of common pool resources. Specifically, all cases analysed in this thesis reveal an important link between the technology capabilities that private actors hold and wish to deploy in the market for mobile communications and their internal negotiations about the withdrawal mechanisms (i.e. internal rivalry) and the exclusion mechanism (i.e. excludability) to be set in place for a given frequency band at either regional or global level. This triangular relationship between technology capabilities as enabling the extraction of resource units, the construction of rule systems as well as the creation of markets derived the sustained governance of a common pool resource has not been sufficiently explored in studies of local or global commons, which remain focused on the most desirable institutional design for a given common good – i.e. climate, oceans, radio spectrum – rather than on the relationship between positions in the resource and positions in the markets derived from activity in the resource.

7.1.4 The Choice of Property Solutions in Transnational Commons

The evidence discussed so far has revealed that, by means of negotiating the configuration of technology systems used to extract value from the radio resource, private users are able to define rule systems in transnational frequency pools without the need for external intervention. These rule systems specify a bundle of property arrangements that, in common pool resources, comprise rights of access and rights of use of a common pool (i.e. operational rights) as well as rights of management and rights of exclusion from the common pool (i.e. collective choice rights[192]) (Cole and Ostrom 2012, Schlager and Ostrom 1992). Given the role of private users in defining rules to govern the commons, the question remains whether these actors are more likely to prefer institutional outcomes that resemble individual exclusive property when

[192] As previously indicated, see supra note 17, this thesis does not focus on the process by which rights of alienation are defined. This is because the right of alienation is defined by public actors at state level, rather than at transnational or international level.

managing a common pool resource such as the radio spectrum, in order to maximise individual withdrawal rates from the resource.

This thesis has made two findings regarding the choice of property solutions in the radio spectrum. The first finding indicates that, in negotiations about rule systems for the creation and utilisation of frequency pools at transnational level, private actors are able to agree exclusion methods for their preferred operations and are able to choose, strategically, whether these exclusion mechanism should be placed at regional (Case I, Case II) or at global level (Case III, Case IV (5GHz). This is an interesting finding, since the "tragedy of the commons" literature proposes intervention by an external body (Hardin 1998), either through government control or through privatisation, as a mechanism to ensure the conservation of a resource pool, due to the supposed inability of individual users to agree collective exclusion mechanisms (Pennington 2012: 23-24).

This relates to the second finding, which shows that private actors are concerned with the individualisation of their property rights in only two of the four cases analysed in this thesis, where there is internal disagreement over individual withdrawal rates resulting from competing technology specifications to be deployed in regional frequency pools (Case I and Case II). In Case III and Case IV (5GHz), when private actors negotiate more comprehensive collective choice mechanisms to mitigate internal conflict, they appear less concerned with the individualisation of their property rights and more concerned with the establishment of system exclusivity (i.e. IMT systems in Case III) or technology exclusivity (i.e. OFDMA in Case IV (5GHz)) in the largest possible frequency pools – i.e. the global frequency pool.

These findings carry two main implications for the literature on property rights in common pool resources and, particularly, in transnational common pool resources. First, these findings confirm that property arrangements in the commons can take the form of both individual exclusive rights (Case I, Case II) and common exclusive rights (Case III, Case IV), depending on the economic interests exhibited in technology negotiations, which focus either on individual withdrawal rates in a regional frequency pool (i.e. rivalry as in Case I and Case II) or on common exclusion of others from a global frequency pool (i.e. excludability as in Case III and Case IV). These findings confirm that both types of property arrangements – i.e. individual exclusive property and common exclusive property – should be recognised as private property that is exclusive to either an individual or a group of individuals (McKean 2000, Pennington

2012). Indeed, in two of the four case studies analysed in the current study, private actors prefer individual private property when they have not invested in the creation of comprehensive collective choice arrangements – i.e. weak information exchange and monitoring of patents in GSM MoU in Case I and in ETSI SMG in Case II – because, in itself, individual private property minimises the requirement for further negotiation and investment in agreements between resource users (Pennington 2012: 30). Conversely, in the other two cases analysed in the current study, private actors prefer flexible or common private property when they have invested in the creation of comprehensive collective choice arrangements – i.e. inclusive decision-making, information exchange and mutual monitoring of the system configuration for IMT-2000 and IMT-Advanced in Case III and for IEEE 802.11 in the Wi-Fi Alliance in Case IV (5GHz) – because common private property facilitates flexibility over future rates of use in larger frequency pool (i.e. global pools). In all cases, however, private actors are interested in limiting access of outsiders to their preferred frequency pool and they achieve this by defining resource boundaries tied to technology specifications (Case I, Case II, Case IV (5GHz)) or system specifications (Case III). This finding illustrates, once again, the relevance of technology capabilities in negotiations among resource users and confirms the position that technology systems are used in the commons not only "to extract value [from the resource] but also to establish and sustain property systems on [it]" (Ostrom in Buck 1998: xiii).

These findings also carry a second implication for the wider discussion about interactions between the private and public regulation of transnational common goods (see *Section 7.2*). The current study shows that, by simply changing the analytical focus from the domestic regulation to the transnational regulation of the radio resource, we observe that private users are considerably more active in the initiation, negotiation and definition of property specifications in this resource. This finding is relevant to the extensive literature on the regulation of the radio spectrum at domestic level, where private resource users gain usufruct rights to the radio resource through a variety of mechanisms – e.g. licenses (non-transferable), licenses (with second markets) or conditioned open access – from a public regulator (Cave 2006, Brito 2006, Benkler 2012). Far from challenging the contribution of this literature to the development of policies aimed to ensure the efficient allocation of usufruct rights in the radio resource, the current study reveals that some aspects of the rights that make up the bundle of property arrangements in the radio resource can be determined at levels of decision-making that supersede the state, such as the transnational level. The current study reveals that, due to the global nature of the radio resource, private actors are specifically interested in negotiating rules that establish forms of collective property exclusion – based on technology, services or systems – at rule-making levels that supersede the state. In this situation, aspects of the excludability of a property right in the radio resource – which is a defining principle of property in the commons because of its purpose to establish boundaries that prevent interference (pollution) or overuse (crowding) – are negotiated outside the boundaries of the state. This finding confirms that collective property rights can be established in global commons, especially if different parts of a bundle of property arrangements are defined at different levels of rule making. As German and Keeler (2012) noted, interactions between these property regimes[193] – e.g. interactions between usufruct rights and collective rights in the radio commons – have not been sufficiently explored in the study of local and global commons. The next section takes these findings forward and explores their contribution to the wider debate about the origin and authority of these transnational private regimes and their interaction with established polities at the domestic, regional and international level.

7.2 The Scope for Private Regulation of Transnational Commons

This thesis has revealed the capacity of private resource users to initiate, negotiate and define operational and, sometimes, collective choice arrangements in the radio resource. These operational rules, which inform the rate of use of a frequency band as well as the principles of excludability that apply to it, form the transnational private regulation of the radio spectrum, which is legitimated by domestic, regional (EU) and international polities. This section considers the dynamics between the private regulation of the radio spectrum and other polities with authority to regulate the radio resource. First, the section considers the extent to which private resource users, organised in industry associations such as GSMA (Case I), NGMN (Case III) or the Wi-Fi Alliance (Case

[193] German and Keeler (2012: 573) referred to these interactions as "hybrid institutions" or "institutional arrangements governing the interdependencies among discrete property holders and regimes, whether defined by structure (linkages among entities with jurisdiction over discrete property regimes) or mode of governance (balance between self-organisation and formal regulation as complementary instruments of governance)".

IV), engage in private regulatory governance. Specifically, it evaluates the role of industry actors as rule makers, monitors or enforcers of a private regime for the governance of the transnational radio resource. Second, it considers the extent to which this associative regime interacts with other polities such as governments, regional executives (European Commission) and international organisations (International Telecommunications Union). Specifically, it considers the nature of complementarity between private and public regimes for the provision and protection of common goods such as the radio resource.

In order to evaluate the contribution of these findings to the governance literature and, more specifically, to the transnational private regulation literature, it is important to understand the principles of difference between transnational private regimes and other types of regimes. Scott, Cafaggi and Senden (2011) define the three features of a transnational private regime as follows. First, they are “transnational, rather than international, in the sense that their effects cross borders, but are not constituted through cooperation of states as reflected in treaties” (2011: 3). Second, they are private or “non-state in the sense that key actors in such regimes include both civil society or non-governmental organisations and firms (both individually and in associations)” (2011: 3). Third, they are regimes because they “address activities characterised in some instances by market-oriented needs for intervention and coordination, as with technical standards, but also provide a response to broader political conflicts over the appropriate balance between states and markets in determining such matters as entitlements to the protection of human rights and conservation of the environment” (Scott, Cafaggi and Senden 2011: 4).

7.2.1 Associative Governance in Transnational Commons

The current study confirms that private resource users, organised in formal (e.g. GSMA in Case I) and informal industry associations (LTE/SAE Alliance, MIB in Case III), have articulated a transnational private regime that meets the conditions established by Scott, Cafaggi and Senden (2011). This finding goes back to the role of private resource users – i.e. service operators and equipment manufacturers of electronic communications – as initiators, negotiators and creators of rules of access and rules of use (i.e. operational rules) in the radio resource during their negotiations about the architecture of technology systems to be deployed in transnational frequency bands. This thesis reveals that, in all the cases analysed, private actors engage in rule making – i.e. the definition of rules of operation in frequency pools – irrespective of the presence or absence of a public actor with authority to set or coordinate the definition of rules in the regional radio resource.

This finding confirms that private actors can hold public roles concerning the management of a transnational common good beyond regulatory spaces established at domestic or international level. Subsequently, the transnational regulation of the radio resource is a good example of rule making power derived from "the freedom of contract and association", rather than from domestic or international law (Scott, Cafaggi and Senden 2011: 15). It reinforces the findings of a growing literature that reveals the substantive nature of private activity conducted by non-governmental organisations and businesses engaged in "regulatory standard-settings" in areas such as labour rights or the environment (Abbott and Snidal 2009). This regulatory activity differs from traditional standardisation processes between private actors at transnational level because it aims to produce property rights for regulatory rather than transactional purposes (Scott 2012: 1326). This thesis reveals the regulatory function of private actors, with ability and capacity to associate in order to set property arrangements in regional or global frequency pools, as well as with ability and capacity to set common standards in order to reduce transaction costs in future communications markets.

In addition, this finding reinforces the position that private actors can serve both individual and collective interests (Ostrom 2008, Scott, Cafaggi and Senden 2011). This is not to say that the rule making process is neutral, which is confirmed by the hard bargaining process between firms with considerable presence in electronic communications markets. It simply implies that private entities can be both rule makers and rule abiders, equally interested in the preservation of a common resource (i.e. regional or global frequency pools free from collaborative or distributional problems of collective action) and interested in the production of common goods (i.e. mobile communications systems). This, once again, confirms that private actors have complex motivational structures, which can equally inform their profit maximisation behaviour and their resource conservation behaviour, without being mutually exclusive. Thus, the rule making activity of industry actors in the radio resource raises questions whether these actors are, by default, rent-seekers interested in "capturing governance arrangements for their particularistic ends" (Abbott and Snidal 2001: 349). In the cases examined here, the difference between rule-making and rent-seeking could be particularly difficult to distinguish, especially because the property arrangements resulting from these private negotiations are products of distributive bargaining about the degree of rivalry and excludability in a limited frequency pool. The key, however, is to understand that the same bargaining process can have both regulatory purposes (i.e. establish property arrangements in the radio resource) and transactional purposes (i.e. reduce costs in communications markets by establishing compatibility standards). This distinction, which has been insufficiently explored in the electronic communications standardisation literature, shows that it is, in fact, inopportune to dismiss private regulation "on grounds that it indicates either cartelisation or capture" (Scott, Cafaggi and Senden 2011: 5). The findings of this thesis align with the growing evidence about the capacity of private actors to protect public goods such as the International Emissions Trading Association to mitigate climate change (Abbott 2012, Hoffman 2013) or to establish voluntary clubs that produce positive externalities such as the Kimberly Process Certification Scheme to control trade in diamonds from regions of conflict (Haufler 2009, Prakash and Potoski 2007). Thus, the findings of this thesis certify that private regulation is not solely concerned with the production of private good or club goods that benefit their members exclusively (Cafaggi 2012b).

Lastly, this finding confirms the increasing capacity of industry actors, organised in industry associations, to diversify the range of solutions to public policy problems (Streeck and Schmitter 1985: 3). The cases put forward in this thesis confirm that a group of private resource users, organised in strategic industry associations, operate an internal logic promoting the collective self-interest, which fits the associative governance described, at the domestic level, by Streeck and Schmitter (1985). Once again, the evidence of collective self-interest does not imply that cleavages do not exist inside the formal or informal associations analysed in this thesis. On the contrary, negotiations within associations (e.g. GSM-CEPT in Case I) and between associations (e.g NGMN and LTE/SAE in Case III) confirm a continuous bargaining process over the degree of rivalry to be defined in a frequency pool. However, they also confirm a collective self-interest about the principles of excludability that should apply in a given frequency pool, which result in the establishment of resource boundaries at regional or global level. This form of associative governance differs from the "spontaneous solidarity" exhibited by local communities in remote locations, the "dispersed competition" exhibited by firms wishing to reduce transaction costs in the market or the "hierarchical control" exhibited by public actors wishing to protect or provide public goods at domestic level (Streeck and Schmitter 1985: 9). Thus, the associative governance identified in the four cases of this thesis should be interpreted as a transnational private regime with a regulatory scope (i.e. establish property arrangements in transnational common pools) as well as a transactional scope (i.e. reducing costs of interaction in the mobile communications markets).

7.2.2 Interactions between Associative and Domestic, Regional or International Polities

The last finding of this thesis is concerned with the variation in associative governance across the four case studies examined here. The thesis finds that, in two cases (Case I and Case II), private actors do not invest in comprehensive collective choice arrangements designed to safeguard operational rules of access and use in a frequency pool. In these cases, private actors have limited self-monitoring capabilities to ensure information exchanges about technology capabilities (e.g. declaring essential patents in ETSI SMG in Case II) or to monitor the technical preferences of participants (e.g. inability of operators to monitor strategic alliances between manufacturers in GSM in Case I). Because, in these two cases, rules of use and exclusion from the frequency pools are not safeguarded by collective choice arrangements agreed internally, private actors rely on the regional public actor – i.e. the European Commission – to monitor and enforce these rules (i.e. Council Directive 87/372/EEC in Case I and Commission Decision 128/1999/EC in Case II). This formal legislation, which contains provisions for service or technology exclusivity in the frequency pool, has the aim to safeguard and legitimise the arrangements agreed upon by private resource users in their respective industry associations. In contrast, in Case III and Case IV (5GHz), private actors invest in more comprehensive collective choice rules, which allow them to monitor internal commitments to operational rules and to rely on public actors only for the enforcement of these arrangements, without the need to specify rules of technology or service exclusivity in the formal legislation. Thus, we find that private actors engage in rule-making in all the cases in this thesis, but they vary in their ability to self-monitor commitments to these rules based upon their level of investment in collective choice arrangements. When self-monitoring is weak, we find a stronger reliance on the public actor to safeguard their arrangements. Lastly, we find that, in all cases, private actors rely on public actors to legitimise and enforce the rules of access and rules of use they agree upon.

These findings reveal the complex dynamics between associative modes of governance and other polities situated at domestic, regional (EU) and international level. First, they confirm that the rule making capacity of private actors is most developed at transnational level, because of "the weaker governmental dimension at global level" (Scott, Cafaggi and Senden 2011: 4). This position confirms that private actors behave differently at domestic level, where they might organise in order to lobby public actors for a particular configuration of usufruct rights in the radio resource, and at transnational level, where they organise in order to produce technical systems and operational rules for the deployment of these systems in regional or global frequency pools. These findings confirm that, by focusing solely on interactions between private and public actors at the domestic level, there is a tendency to overstate the presence of regulatory capture (Novak 2014) as well as to overstate the motif of private actors to capture public rule makers (Scott, Cafaggi and Senden 2011, Scott 2012).

This position is confirmed by the findings put forward in this thesis, which reveal that the presence of the European Commission – as an agenda setter at the regional level – does not reduce the willingness of industry actors to engage in private rule making. On the contrary, in Case II, industry actors engage in private rule making in order to shift the technology preference of the European Commission for a revolutionary B-ISDN system in favour of the industry preference for an evolutionary GSM system, so as to maintain their preferred configuration of rivalry and excludability in the frequency band of interest. These findings have two implications for the EU governance literature. First, they question the vision of the European Commission as the corporate actor who initiates and coordinates corrective measures for the negative and positive integration of the single market (Fuchs 1995). Second, they support the presence of a multi-level governance approach in the European Union (Eising 2004, Fuchs 1994), with considerable variability across policy issues, based on the capacity of private interests to organise within the EU polity (Kohler-Koch and Eising 1999, Knill 2001) as well as on their willingness to organise at other levels of decision-making. In fact, these findings confirm the presence of vertical cooperation between the associative regimes established by transnational private regulation in the radio resource and regional polities such as the EU (Case I and Case II) or international polities such as the ITU (Case II, Case III and Case IV). They confirm that, increasingly, regulatory standards developed by private actors in transnational regimes are legitimised, incorporated and endorsed by domestic or regional legislators in a form of "vertical complementarity" (Cafaggi 2014), rather than being created by those jurisdictions themselves. Similar evidence of vertical complementarity has been found in the regulation of advertising, civil aviation and food safety certification (Cafaggi 2014, Scott 2012). However, domestic, regional and international polities have a key role in this relationship because they confer statutory recognition to private regimes that, often, lack this legitimation due to their transnational nature (Abbott and Snidal 2009, Scott, Cafaggi and Senden 2011, Scott 2012).

Overall, this thesis has found considerable evidence of associative governance by private actors involved in the initiation, negotiation and definition of rules of use and rules of access (i.e. operational rules), which regulate the radio spectrum as a global common. However, the thesis has also revealed that this transnational private regime, which originates with industry actors, relies on the authority of domestic, regional and international polities in order to be legitimated. These findings contribute to the evidence base on the hybrid nature of governance and the polycentric distribution of authority between public and private actors in the provision and production of transnational common goods (Ostrom 2010, Scott, Cafaggi and Senden 2011). They support the capacity of private actors to sustain policy-making functions, while substantiating the existence of mutually reinforcing, rather than mutually exclusive, jurisdictions that contribute to the definition, monitoring and enforcement of property arrangements in transnational commons.

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